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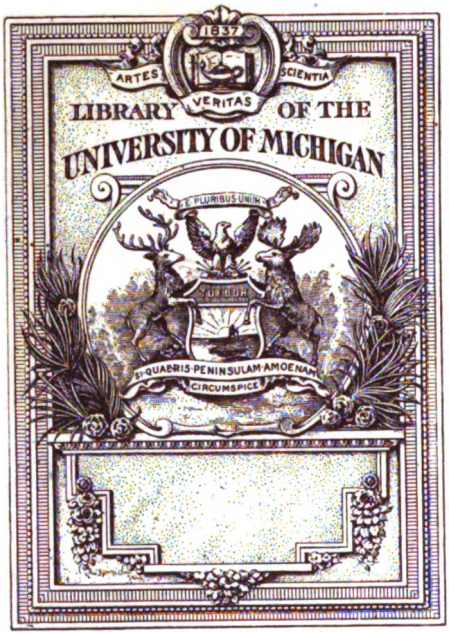

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THE

Mineralogical Magazine

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY.

VOLUME V.

LONDON:
SIMPKIN, MARSHALL & Co., STATIONERS' HALL COURT.

MDCCCLXXXIV.

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LONDON:
PRINTED BY WILLIAMS AND STRAHAN,
LAWRENCE LANE, CHEAPSIDE.

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No. 1. Ledbeg rock, cut *parallel* to the bedding.

No. 2. The same, cut *transverse* to the bedding.

3. The Dolomite of Ledbeg, taken a few inches from the dark rock.

The slice shows *a barred structure*, which consists of twinned dolomite, or possibly dolomite with plates of calcite. Clear angular patches, with a delicate tufted structure: these are probably Wollastonite. A ring-like structure, with occasionally processes connecting the inner sides of the rings. These somewhat resemble the "Canal structure" of Eozoon, but consist of granules of malacolite passing into serpentine.

4. An igneous rock from the south shore of Loch Assynt. Augite with imbedded crystals of olivine; Enstatite (?); and tufted dark serpentine, with small patches of magnetite.

5. Schiller spar from Beauty Hill, Aberdeenshire. Large foliated enstatite, with included olivine; the latter not only margined and intersected by bands of serpentine, but throwing out processes of the latter, which ramify through the enstatite.

6. Laurentian gneiss, from Unapool, Sutherland. This singular rock contains rude crystals of Augite, which are sprinkled throughout with minute crystals of a striated felspar, and are incased in a sheath of radiating foliaceous crystals of hornblende. Large crystals of plagioclase (? oligoclase) and strangely formed masses of magnetite lie between the crystals of augite.

7. Chrysotile, forming a reticulated structure in vein serpentine, from Colafirth Voe, Shetland. This bears some resemblance to the general arrangement of parts in Eozoon Canadense.

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ERRATA.—VOL. V.

ERRATA TO No. 22.

Page 8, line 3, after "points of contact," *read*
"In the 29th volume of the second series of the *Edinburgh Philosophical Journal*, I have found the following interesting note by Neckar:—"Gallinase of Beal in Skye differs from pitchstone in specific gravity, and by its fusion before the blowpipe into a black scoriaceous enamel. It forms a crust of two or three inches on a basaltic dyke, which traverses the whole valley of Beal, like a prominent wall of basaltic pillars. Probably the vitreous dykes of Caosaigin Mull, and Lamlash are the same." This is evidently tachylite; and it is interesting to have made out what "Gallinase" is, and to have a note of some of its localities. The foregoing contracted analyses of tachylite and pitchstone, however, show differences which external characters could not disclose; and make it markedly evident that tachylite is the slag of a *basic* rock, and pitchstone that of an *acidic* one."

Page 19, line 15, for "turned" *read* "termed."

Page 29, line 5 from bottom, for "71·793" *read* "71·801."

,, last line, for "100 085" *read* "100·574."

Page 43, line 9 from bottom, for "designed" *read* "designated."

Page 46, line 6 from bottom, for "many contains" *read* "contains many."

ERRATA TO No. 23.

Page 82, line 14, for "convoluted" *read* "*un*convoluted."

Page 87, line 2 from bottom, for "rarely" *read* "usually."

Page 111, line 2 from bottom, for "Port" *read* "Post."

Page 113, line 10, for "CO" *read* "Co."

ERRATA TO No. 24.

Page ix., line 8, for "Thompson" *read* "Thomson."

Page 190, line 2, ,, ,, ,, ,,

Page 191, *add* "The cuts are ½ full size."

Page 194, line 9 and 11 from bottom, for "Euphotides" *read* "Gabbros."

Page 195, line 7 from top, after "appliances" *add* "whilst abroad."

Page 196, line 14 from top, after "manner" *add* ";"

ERRATA TO No. 25.

Pages 268, 269, for "Wük" *read* "Wuk."

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EXCERPT MINUTES OF COUNCIL MEETING,

Held at Victoria Street, June 3rd, 1882.

W. H. Hudleston, M.A., F.G.S., President, in the Chair.

The following noblemen and gentlemen were duly elected Members—

The Duke of Argyll, K.T., F.R.S., Inverary.
The Earl of Breadalbane, Taymouth, N.B.
James J. Dobbie, Esq., Glasgow.
J. Stuart Thompson, Esq., Addiewell, West Calder.
Rev. Prof. T. Wiltshire, F.G.S., Lewisham.

A GENERAL MEETING OF THE SOCIETY

Was held on Saturday, June 3rd, 1882, at 116 Victoria Street,

W. H. Hudleston, M.A., F.G.S., President, in the Chair.

The Minutes of the last Meeting, December 4th, 1881, were read and confirmed.

The following papers were read—

Prof. M. F. Heddle, "On a New Mineral Locality in Skye." (p. 115.)

J. H. Collins, F.G.S.—"On some Cornish Tin-stones and Tin Capels." 3rd paper. (p. 121.)

J. J. Dobbie, D.Sc. (communicated by the Secretary)—"Note on a variety of Saponite." (p. 131.)

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EXCERPT MINUTES OF COUNCIL MEETING,

Held at 116 *Victoria Street, October* 24*th*, 1882.

W. H. Hudleston, M.A., F.G.S., President, in the Chair.

The following were elected Members—

John Ernest Ady, St. Domingo House, Oxford Gardens, Notting Hill, London, W.
Dr. C. Callaway, Wellington, Salop.
Hjalmar Gylling, Doctor of Philosophy, Helsingfors.
John James Hamilton, Ardendee, Kirkcudbright.
Rev. Canon Harford, "The Little House," 4a Dean's Yard.
William Jolly, H.M. Inspector of Schools, Inverness.
Mr. W. Ivison Macadam, Lecturer on Chemistry, Surgeon's Hall, Edinburgh.
W. S. Peebless, 41 Granville Park, Lewisham, S.E.
T. Tyrer, F.C.S., F.I.C., Garden Wharf, Battersea, S.W.

It was resolved that, for the present Session, meetings be held on the following dates—

December 12*th*, 1882,
February 15*th*, 1883,
May 15*th*, 1883,
October 23*rd*, 1883 (*Anniversary*).

The Meeting in May to be held in Scotland.

EXCERPT MINUTES OF COUNCIL MEETING,

Held at the Museum, Jermyn Street, Dec. 12*th*, 1882.

W. H. Hudleston, M.A., F.G.S., President, in the Chair.

The following gentleman was elected a Member—

Colonel C. A. McMahon, Commissioner, Amritsar, Punjab.

It was resolved, on the recommendation of the General Secretary, that the printing and publication of the Magazine be transferred from Messrs. Lake & Lake, of Truro, to Messrs. Williams & Strahan, 7 Lawrence Lane, Cheapside.

EXCERPT MINUTES OF COUNCIL MEETING,

Held at 116 *Victoria Street, March* 12*th*, 1883.

W. H. Hudleston, M.A., F.G.S., President, in the Chair.

The audited accounts for 1882 were submitted, with the statement of assets and liabilities.

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Abstract of Receipts and Payments of the Mineralogical Society, from 1st January to 31st December, 1882.

RECEIPTS.	£	s.	d.
Balance on 1st January, 1882	5	8	8
Subscriptions paid in advance	1	1	0
„ for current year	95	6	11
„ for previous year	13	18	0
Life Composition	10	10	0
Entrance Fees	14	19	0
Sale of Publications	79	3	4
One year's Dividend on New Three per Cent. Annuities	4	3	9
Sundries	0	4	2
Balance due by the Society	6	2	9
	£230	17	7

PAYMENTS.	£	s.	d.
Printing	105	4	8
Illustrations	101	8	10
Expenses at Meetings	0	5	0
Clerical Expenses	2	2	0
Postage and Parcels	16	15	7
Investments of Dividends	4	3	9
Advertising and Incidentals	0	17	9
	£230	17	7

Examined and found correct.

(Signed) BENEDICT KITTO, F. W. RUDLER, } Auditors.

Assets and Liabilities *on 31st December*, 1882.

LIABILITIES.	£	s.	d.
W. & A. K. Johnston, Plates	13	6	8
Autotype Company, „	8	11	0
V. Brooks, Day & Son „	6	6	6
Lake & Lake, Printing and Plates	22	19	10
Wightman & Co., Printing	3	10	3
Subscription paid in advance	1	1	0
Clerical Expenses	5	0	0
Cash overdrawn	6	2	9
Excess of Assets over Liabilities	174	19	1
	£241	17	1

ASSETS.	£	s.	d.
Subscriptions for 1882 unpaid	16	15	0
Fees „ „	5	5	0
Subscriptions for 1881 „	8	7	0
New Three per Cent. Annuities, £142 14s. 8d. at 101	144	3	1
Stock of Publications (average yearly sale)	50	7	1
Sales by Publishers (unpaid)	16	19	10
	£241	17	1

ROBERT H. SCOTT,
General Secretary.

M.

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THE ANNIVERSARY MEETING OF THE SOCIETY

Was held at 116 *Victoria Street, Oct.* 24*th*, 1882.

W. H. HUDLESTON, M.A., F.G.S., President, in the Chair.

The Voting Papers, 47 in number, for the Officers and Council, were submitted, and the following were found to be duly elected—

President.	W. H. HUDLESTON, M.A., J.P., F.G.S.
Vice-Presidents.	REV. S. HAUGHTON, M.D., F.R.S.
	REV. PROF. T. G. BONNEY, M.A., F.R.S.
Past-Presidents (*Members of Council under Rule* 14)	H. C. SORBY, Esq., F.R.S.
	PROF. M. F. HEDDLE, M.D., F.R.S.E.
Council.	PROF. A. H. CHURCH, F.C.S.
	T. DAVIES, F.G.S.
	T. W. DANBY, M.A., F.G.S.
	JAMES GEIKIE, F.R.S.
	T. G. GIBB, Esq.
	T. M. HALL, F.G.S.
	M. HAWKINS JOHNSTON, F.G.S.
	JAMES I'ANSON, F.G.S.
	JAMES S. MERRY, F.C.S.
	REV. W. W. PEYTON.
	H. M. PLATNAUER
	J. F. WALKER, F.G.S.
Trustees.	THE LORD DE BLAQUIÉRE, F.R.G.S.
	PATRICK DUDGEON, F.R.S.E.
General Secretary.	ROBERT H. SCOTT, M.A., F.R.S.
Foreign Secretary.	C. LE NEVE FOSTER, M.A., D.Sc., F.G.S.
Local Secretaries.	Cornwall. B. KITTO, F.G.S.
	Lancashire. T. A. READWIN, F.G.S.
	Central Scotland. REV. W. W. PEYTON.
Auditors.	B. KITTO, F.G.S.
	F. W. RUDLER, F.G.S.

The following Report was read and adopted—

"The Council, on the completion of the Sixth Year of the Society's existence, has to congratulate the Members on the appearance in the last part of the Journal of a balance-sheet showing a healthy financial position.

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"The balance in the Treasurer's hands at the foot of that account was but small, £5 8s. 8d., but the statement of Assets and Liabilities shows that the debt to our printers, which stood at £230 16s. 6d. on the 31st of December, 1880, had been reduced to £94 10s. 7d. * at the corresponding date in 1881.

"This old debt has now (July, 1882) been completely cleared off, and the only accounts outstanding are for printing and illustrations of the numbers of the Journal issued in the course of the year 1882, which will come to be paid at the end of the year.

"It will be seen that the item "Estimated Value of Stock of Journal (£185), has been replaced by an entry of the average Annual Sale of the Journal (£36 19s.), as representing the income to be expected from that source. The value of the Invested Stock of the Society appears also for the first time as an asset.

"The final result shows an excess of assets over liabilities amounting to £111 14s. 4d.

"At the York Meeting, an addition was made to the Rules, providing for the removal from the list of names those of Members three years in arrear. In accordance with that resolution four names have been struck off.

"Death has also taken from us one corresponding member—Pastor Esmark, of Christiania, one ordinary member—Mr. J. Gilchrist Clark, and one associate—Mr. J. Maynard.

"Resignations have been rather numerous, amounting to 6 among the members and 1 associate.

"The elections, on the other hand, have more than made up for our losses, as they number 18 members and 1 associate, so that our total is slightly increased.

"It is, however, evident that with little over 100 subscribing Members, the expenditure on the Journal requires careful supervision, and that the Council have been fully justified in continuing to restrict its issue, so as not to encumber the Society with debt.

"The chief contributor to the Journal has been our late President, Dr. Heddle, whose magnificent Map of Sutherland was distributed in February, as part 21, while part 22, issued in May, contained a paper by him on Minerals new to Britain. The third portion of his Geognosy of

* Amount due, £121 1s. 8d., less by Sales, £26 10s. 8d.; balance, £94 10s. 7d.

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Sutherland appears in part 23, which will soon be placed in the hands of Members.

"Part 22 contained also a most suggestive and interesting paper by Messrs. J. I'Anson and E. A. Pankhurst on the Structure of Agates, which was beautifully illustrated with drawings by Mr. I'Anson, reproduced by the Autotype Process.

"Two General Meetings have been held during the year, both in London, the first in December, 1881, the second in June, 1882, and the Council have under consideration the advisability of holding in future regular—say, Quarterly—Meetings at fixed dates."

The following papers were read—

"On a Portable Blowpipe Lamp." By J. Stuart Thompson. (p. 190.)

"On Colliery Refuse." By G. M. Ward. (Abstract p. 192.)

"On Oregon Nickel." By Prof. Hood (communicated by the Foreign Secretary). (Abstract p. 192.)

Mr. Davies exhibited a fine specimen of Microlite from Virginia.

Mr. Henson exhibited Crystals of Danburite from Bergscopi, Canton Grisons, Switzerland.

Mr. Gibb exhibited Dodecahedral Argentite from Chili.

GENERAL MEETING,

Held at the Museum, Jermyn Street, Dec. 12th, 1882.

W. H. Hudleston, M.A., F.G. S., President, in the Chair.

The following paper was read—

"On some Rocks from the Saas-grat compared with Erratic Blocks from the neighbourhood of Lake Leman." By Capt. Marshall Hall, F.G.S. (p. 193.)

GENERAL MEETING,

Held at the Museum, Jermyn Street, Feb. 15th, 1883.

W. H. Hudleston, M.A., F.G.S., President, in the Chair.

Professor A. H. Church exhibited a remarkable silicious concretion from the Upper Greensand of Haldon, Exeter. It closely resembles the menilite of Ménil Montaut, and Argenteuil, near Paris, but is not in reality a form of the liver opal occurring in those localities. A specimen similar to that shown gave on analysis the following percentages :—

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Water	1·05
Silica	96·33
Alumina and Ferric Oxide	2·74
Lime	traces
	100·12

Mr. W. Vicary, of Exeter, to whom Mr. Church was indebted for the specimens of this mineral, finds the concretions distributed but very sparsely throughout the entire thickness of the Haldon beds, and does not consider them in any way related to *beekite*.

The President read a paper "On a Recent Hypothesis with respect to the Diamond Rock of South Africa."

A paper was read from Mr. J. H. Collins, F.G.S., "On the Minerals of Rio Tinto."

(*These Papers will appear in No.* 25.)

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EXCERPT MINUTES OF COUNCIL MEETING.

Held at 116 *Victoria Street, July* 18*th*, 1883.

W. H. HUDLESTON, Esq., M.A., President in the Chair.

MR. J. J. HARRIS TEALL, M.A., F.G S., was elected a Member.

MR. T. VAUGHAN HUGHES, A.R.S.M., was elected an Associate.

EXCERPT MINUTES OF COUNCIL MEETING.

Held at the Museum, Jermyn Street, October 23*rd*, 1883.

W. H. HUDLESTON, Esq., M.A., President, in the Chair.

The following gentlemen were elected Members—

ALEXANDER ROSS, Esq.
W. R. TAIT, Esq.
T. H. HAMPTON, Esq.

PROFESSOR LUDWIG, of Vienna, was elected a Corresponding Member.

A letter was read from Prof. W. J. Lewis, proposing terms of amalgamation with the Crystallological Society, which were accepted.

It was resolved, that the meeting in December be made Special, for the purpose of election *en bloc* of the Members of the Crystallological Society.

EXCERPT MINUTES OF COUNCIL MEETING.

Held at the Museum, Jermyn Street, December 11*th*, 1883.

The REV. PROF. BONNEY, D.Sc., F.R.S., President, in the Chair.

The names of certain gentlemen, in arrear with their subscriptions, were ordered to be removed from the list.

EXCERPT MINUTES OF COUNCIL MEETING.

Held at the Museum, Jermyn Street, February 12*th*, 1884.

The REV. PROF. BONNEY, D.Sc., F.R.S., President, in the Chair.

The audited statement of accounts for the year 1883 was submitted and ordered to be issued. (see p. xviii.)

The following Associates were elected Members—

MR. W. SEMMONS.
MR. T. VAUGHAN HUGHES.

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The following corresponding Members of the Crystallological Society were elected corresponding Members—

Mr. E. Bertrand, Paris.
His Serene Highness the Grand Duke of Leuchtenburg.
Prof. Victor Von Lang, Vienna.

The Editing Committee for the current year was constituted as follows—

The President.
Mr. T. Davies.
Mr. L. Fletcher.
Mr. W. Hudleston.
Mr. R. H. Scott.

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Mineralogical Society—Abstract of Receipts and Payments from 1st January to 31st December, 1883.

RECEIPTS.

	£	s.	d.
Subscriptions paid in advance	2	7	0
,, for current year	84	17	0
,, for arrears	3	13	0
Entrance Fees and Life Compositions	29	13	0
Sale of Publications	21	13	4
Dividends	4	14	4
Sundry small items	0	3	6
	£147	1	2

PAYMENTS.

	£	s.	d.
Balance from 1882 (overdrawn)	6	2	9
Printing	47	18	7
Plates	41	14	8
Expenses of Meetings	2	1	4
Clerical Expenses (1882)	5	0	0
Postages, Parcels, &c.	8	8	2
Investments	18	14	4
Sundry small items	0	1	0
Balance in hand and at Bank	17	0	4
	£147	1	2

Examined and compared with the Vouchers and found correct. (Signed)

F. W. RUDLER,
B. KITTO, } AUDITORS.

LIABILITIES.

	£	s.	d.
Wightman & Co., Printing	1	15	0
S. Miller, Plates	8	7	6
Williams and Strahan, Printing	55	16	0
Clerical Expenses (1883)	5	5	0
Subscriptions paid in advance	2	7	0
Excess of Assets over Liabilities	191	10	6
	£265	1	0

ASSETS.

	£	s.	d.
Subscriptions for 1883, unpaid	25	14	0
,, ,, 1882 ,,	7	12	0
,, ,, 1881 ,,	2	2	0
New Three per cents. £160 18s. 5d. at 101¼	162	18	9
Stock of Publications (average yearly sale)	45	2	6
Sale of Publications unpaid—Simpkins	17	1	3
,, ,, ,, Quaritch	1	12	3
,, ,, ,, Secretary	2	18	3
	£265	1	0

Examined and compared with the Vouchers and found correct.

ROBERT H. SCOTT,
General Secretary.

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THE ANNIVERSARY MEETING OF THE SOCIETY.

Held at the Museum, Jermyn Street, Oct. 23rd, 1883, at 8 p.m.

W. H. HUDLESTON, M.A., J.P., F.G.S., President, in the Chair.

The Voting Papers, 44 in number, for the Officers and Council, were submitted, and the following were found to be duly elected—

President. REV. PROF. T. G. BONNEY, D.Sc., F.R.S.

Vice-Presidents. REV. S. HAUGHTON, M.D., F.R.S.
W. H. HUDLESTON, M.A., F.G.S.

Council in place of Messrs. Danby, Church, Merry and Walker.
G. S. BOULGER, F.G.S.
C. O. TRECHMANN, Ph.D., F.G.S.
J. STUART THOMSON, Esq.
REV. PROF. T. WILTSHIRE, M.A., F.G.S.

Treasurer. R. P. GREG, F.G.S.

General Secretary. ROBERT H. SCOTT, M.A., F.R.S.

Foreign Secretary. C. LE NEVE FOSTER, D.Sc., F.G.S.

The Secretary read the following Report of the Council—

REPORT.

The Seventh Annual Balance-sheet of the Society, being that for the year 1882, which appeared in Part XXIV., exhibited the most satisfactory financial statement which has yet been presented to the members.

There appeared, it is true, an adverse balance of £6 2s. 9d. at the foot of the account; but, on the other hand, the bills outstanding were small in amount, and the final excess of Assets over Liabilities was £174 19s. 1d., being an increase of £63 4s. 9d. on the corresponding figures from the previous balance-sheet.

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The over-draft had been caused by the necessity of paying off, before the close of the year, Messrs. Lake, the former printers.

The Society having found that inconvenience resulted from the employment of printers resident in Cornwall, resolved to transfer their custom to a London firm,—Messrs. Williams & Strahan (7 Lawrence Lane, E.C.), and the change was effected in January.

The number of Members shows a slight increase on the total from the previous year, as the elections have been 12, viz. : 11 Members and 1 Associate. The losses by death have been three, Mr. Grieve, of Burnt Island ; Monsieur Micault ; and, among the Corresponding Members, Prof. von Kobell, whose place among mineralogists it will be hard to fill.

There have been four resignations, and two names have been removed for non-payment of subscriptions for three years.

The Council have considered that the time has come to make a revision of the terms of election of Associates ; and they submit to the Meeting some suggested modifications of the rules bearing on that subject.

Only two parts of the Journal have appeared during the year, a third, however, will very speedily be distributed to the Members.

It will be seen that Professor Heddle is again by far the most active of the contributors ; and though the Council have to thank most warmly the President, Mr. Collins, and others who have sent in Papers, they cannot but point out that the proportion of Members who contribute original matter is extremely limited, and that unless materially increased activity is displayed, the Journal cannot continue to command the sale which it has attained during the last two years.

Three meetings have taken place during the year, in London ; and by kind permission of the Director-General of the Geological Survey, they have been held in the theatre of the Museum of Economic Geology.

On the motion of Mr. Henson, seconded by Mr. Gregory, the Report was adopted.

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The following alterations of the Rules, of which notice had been duly given in accordance with Rule 29, were then successively submitted, and unanimously adopted.

Rule 4, Add, "And the Council may revise the qualifications of Associates elected after the 1st November, 1883, at the expiration of three years from their election."

Rule 7, Add, "Or from Associates of three years' standing."

Rule 12, Add, "And the Council shall have power to coopt Members to fill any vacancies, caused either by death or by resignation, occurring in the interval between two Anniversary Meetings."

The President then delivered the following Address:—

Gentlemen, this concludes the ordinary business brought before the present Annual Meeting, but there are certain topics of interest to which I may allude previous to the commencement of the General Meeting for scientific work, which will be held forthwith under the presidency of my successor, Professor Bonney.

In the first place, I am happy to say that it is not the custom for the Presidents of this Society to deliver an address, and therefore I shall not have to trouble you with any lengthened remarks, but merely to make a few passing allusions to the present condition and prospects of the Mineralogical Society.

In February of the present year we completed our first Septennial stage, and the last two years of this stage may be regarded as what the old geologists would have called the "transition" period, although in these days we recognise a certain amount of transition *in all periods*. Certainly these last two years have witnessed important changes with us, which, although they are not yet fully recognised, nevertheless materially affect the working of our constitution as a society.

Thus its peripatetic and yet local character has been undergoing modification; and it is evident that the tendency of everything towards London has been felt to an extent which the first founders could hardly have contemplated. It very often happens that, on the constitution of a new body, the enthusiasm of the recently enrolled members carries it through many difficulties; and so, I believe, that some of the very earliest meetings of this Society at various provincial centres were successful in point

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of attendance. But the thing could not last. If proof was required of how matters are changed since those days, we could not have a stronger one than the fact of there having been no country meeting in May last, although a day in that month was fixed and advertised beforehand for a meeting to be held at some place in Scotland. Thus we are prepared by the force of circumstances to have the Mineralogical Society located in London, whither it has naturally gravitated. Yet I trust that the "country" character of the Society will not be suffered to die out, but that at least once in each year a successful meeting may be convened out of London.

There is another point of importance to which I should allude, viz. our financial position. Two years ago, owing to the large amount of matter published, we were heavily in debt to our printers, Messrs. Lake and Co.; the only other serious item of expenditure being the remuneration to the ex-secretary, Mr. Collins. Altogether at that juncture the financial outlook was not very favourable. Mr. Scott has grappled with the difficulty most successfully. In doing the work of General Secretary without fee, beyond a trifling sum to one of his clerks, a pressure on the resources of the Society has been removed, whilst at the same time the expenses of publication have been kept within bounds. The result is that the large debt to Messrs. Lake and Co. has been entirely cleared off, and we can now look our compounders in the face with a very respectable item in the shape of assets, and no liability of any serious import.

This position, of course, has not been attained without some corresponding disadvantages; thus the less frequent appearance of the journal during the last two years has no doubt caused dissatisfaction in some quarters, and may possibly have led to a few resignations, yet in spite of all this we keep up our numbers, and indeed there is a slight increase during the past year. Moreover this subject of publication reminds me, I should say, of another point of importance, viz. the paucity of matter brought before the Society of late. This is very properly mentioned in the Report. It is only fair to admit that Dr. Heddle has been mainly instrumental in keeping us before the public in respect of publication, and if severer critics maintain that portions of his papers are not

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mineralogical, scarcely indeed scientific, it should be borne in mind that but for these papers the Journal would have been very attenuated indeed. There can be no doubt that Dr. Heddle's papers, and more especially his maps, have helped us in more ways than one.

And this brings me to a very crucial question, viz. whether the Mineralogical Society is not covering ground already occupied by the Geological Society. This is the view taken by some, who have held aloof alike from us and from the Crystallological Society. It is perfectly certain that the founders of the Geological Society intended to further, amongst other things, the study of mineralogy, as is amply shown by the papers of Macculloch, William Phillips, and other authors in the earlier "Transactions." But there was a time in the history of the Geological Society when palæontology and the allied studies had almost ousted anything approaching mineralogy. It is true that, since Dr. Sorby occupied the chair and Professor Bonney became the senior secretary, a marked change has taken place, but the feelings engendered amongst mineralogists by the former preponderance of the biological element are not altogether forgotten.

And now I must allude to a subject which, I feel sure, has been uppermost in the minds of us all, and that is, the proposed union with the Crystallological Society. This, as you are aware, is not a numerous body, but includes men of eminence, devoted to the more scientific aspect of mineralogy. Two of them already belong to us, and there may be about ten or a dozen more. Without doubt an amalgamation would be highly beneficial to both parties, the resultant being perhaps a society more purely mineralogical than that which now exists. *We* should bring a comparatively large body with funds and a well-established journal; *they* would bring a small body—mostly men who are likely to be workers and of high repute. Negotiations were commenced in earnest during the past summer, and conducted on our behalf through Mr. Scott, on behalf of the "Crystallological" through Mr. Lewis. The basis of a treaty has been outlined by these two gentlemen, and this has in substance been confirmed, after due consideration, by the Council to-day. I must request the secretary to be kind

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enough to read you that portion of the Minutes of the Council just held which bears upon this question.

[Minutes read.]

There is no provision in our Rules for any such event as fusion with another society, and therefore a special meeting must be convened for that purpose. It is probable that the December meeting of our Society will be made special for the purpose of entertaining the question of amalgamation in accordance with the minutes which have just been read to you. Due notice will be given to all members.

It only remains for me to offer the thanks of this meeting to the Director General of the Geological Survey for his kind permission to meet in this place; and herewith I would associate the name of Mr. Rudler, who has ever been one of our best friends.

Lastly, I beg leave to propose, in due form, a vote of thanks to our Secretary, Mr. Scott, whose services to us have been made so obvious by what I have already stated. He has managed our finances, looked after the editing of the Journal, and conducted our negotiations, all with his usual energy and skill, nay, more, whenever we required a home there was one always ready at the Meteorological Office. All this trouble had been undertaken without any pecuniary compensation whatever, and it was impossible to estimate too highly the work which Mr. Scott had performed for the Society.

Mr. Hawkins Johnson, in seconding this vote of thanks, fully endorsed the President's remarks as to the value of Mr. Scott's services to the Mineralogical Society.

Put and carried by acclamation.

The President then vacated the chair, which was taken by his successor the Rev. T. G. Bonney.

On the motion of Mr. Danby, seconded by Mr. T. Davies, the best thanks of the Society were tendered to the outgoing President for his conduct in the chair during the past two years.

The following Papers were read:—

"Note on Crystals of Calamine from Wanlockhead, Dumfriesshire." By J. Stuart Thomson.

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"On the Occurrence of "Evansite" in Cheshire." By A. S. Woodward (communicated by T. Davies, Junr.).

Mr. Henson exhibited a magnificent specimen of *Stibnite* from Japan, containing about 120 crystals; the total weight being 150 lbs.

GENERAL MEETING.

Held at the Museum, Jermyn Street, Dec. 11th, at 8 p.m.

The Rev. Prof. Bonney, D.Sc., F.R.S., President, in the Chair.

The following papers were read—

"On some Specimens of Lava from Old Providence Island." By the President.

"On the Evidence of the Occurrence of Nickel-Iron with Widmanstätten's Figures in the Basalt of North Greenland." By Prof. K. J. V. Steenstrup (Cor. Memb.).

"On the Chemical Constitution of the Telluric Iron from Greenland." By Dr. J. Lorenzen (communicated by the Secretary).

"Note on a New Mode of Ocurrence of Garnet." By H. Louis.

At the hour of 9 p.m., the Meeting was made special, pursuant to notice, for the purpose of suspending the first ten words of Rule 7, "Ordinary Members shall pay an entrance-fee of £1 1s.," in order to admit of the election *en bloc* of the Members of the Crystallological Society.

SPECIAL GENERAL MEETING.

Held at the Museum, Jermyn Street, at 9 p.m.

Rev. Prof. Bonney, D.Sc., President, in the Chair.

It was proposed by Mr. Hudleston, seconded by Mr. Hawkins Johnson, and carried unanimously—

"That the first ten words of Rule 7, 'Ordinary Members shall pay an Entrance Fee of £1 1s.,' be suspended."

It was then proposed by Mr. R. H. Scott, seconded by Mr. Hawkins Johnson—

"That the Members of the Crystallological Society, be elected Members of the Mineralogical Society."

The motion being put from the chair, was carried unanimously.

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GENERAL MEETING.

Held at the Museum, Jermyn Street, February 12th, 1884.

Rev. Prof. Bonney, D.Sc., President, in the Chair.

The following papers were read—

"On a case of Replacement of the Quartz Constituent of a Granite by Fluor Spar," By the President.

"On an Arsenical Copper Ore, '*Garby-ite*,' from Montana, U.S.A." By Mr. W. Semmons (Associate).

"On an altered Siderite from Alston Moor." By Dr. C. O. Trechmann.

"Notes on a Picrite (Palæopicrite) and other Rocks from Gipps Land, and a Serpentine from Tasmania." By the President.

Prof. Judd, F.R.S., on invitation of the President submitted some slides of dust from the Volcano of Krakatoa, which were exhibited under the microscope, and he explained the principal features noticeable in these deposits.

The President exhibited some slides of dust from Cotopaxi, which had fallen on Chimborazo at the time that Mr. E. Whymper was ascending the latter mountain.

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PROCEEDINGS

OF THE

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

1881.

EXCERPT MINUTES OF COUNCIL MEETING

Held at the Albert Rooms, Stonygate, York, Sept. 2nd, 1881.

Prof. M. F. Heddle, F.R.S.E., President, in the Chair.

The following gentlemen were duly elected Members of the Society.—

James Brebner, Esq., M.A., Dundee.

J. A. Harvie Brown, Esq., Dunipace, Scotland.

R. F. Mallet, Esq., Geol. Survey, India.

Mons. F. Micault, St. Brieuc, France.

The following resolution was adopted.

"That the authors of all papers which are printed in the Magazine shall in future defray one third of the cost of all such coloured illustrations of their papers as have been approved by the Editing Committee, but that there shall be nothing in this resolution to prevent an author from withdrawing such illustrations, if he considers the estimate to be excessive; nor shall there be any thing which shall prevent the Editing Committee on the one hand, or the author on the other, from undertaking the whole cost of such illustrations in the event of there being any difficulty, or difference of opinion, as to the estimate; it being always understood that the question of admission of all such illustrations is to be determined by the Editing Committee, subject, of course, to the ultimate decision of the Council."

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THE SIXTH ANNUAL GENERAL MEETING OF THE SOCIETY

Was held on the 2nd of September, 1881, *at 4 p.m., at the Albert Rooms, Stonygate, York.*

PROF. M. F. HEDDLE, F.R.S.E., President, in the Chair.

The Minutes of the last two Meetings of Feb. 15th and March 30th were read and confirmed.

The Auditor's certificate of the scrutiny of the balloting papers for Council and Officers was read, and the following were declared duly elected for the ensuing year,

President—W. H. HUDLESTON, M.A., J.P., F.G.S.,

Council—T. DAVIS, F.G.S.,
JAS. GEIKIE, F.R.S.,
M. HAWKINS JOHNSON, F.G.S.,
H. LOUIS, Esq.
REV. W. W. PEYTON,

in place of Messrs. Collins, Flight, Greene, Hudleston and Scott.

General Secretary—R. H. SCOTT, F.R.S.

On the motion of Mr. Greg, seconded by Mr. Sorby, the warmest thanks of the Society were unanimously tendered to Dr. Heddle for his services as President during the last two years.

The following Report of the Council for the past year was read and adopted.

"The Society has now completed the fifth year of its existence, and its numbers show a slight improvement, though their total remains, as in the last two years, at 172.

"The number of ordinary members has been increased by two, whilst that of the Associates has been diminished by an equal amount.

"The precise figures at present are:

Corresponding Members	24
Ordinary Members .	126
Associates	22
Total	172

"The balance sheet, which appeared with Part 20 of this Magazine, exhibits a balance in the Treasurer's hands of £42 4s. 3d., but the statement of assets and liabilities shows that since the date of the last balance sheet the expenditure on printing has been larger than was justified by the

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condition of the Society's finances. The debt to our printers, outstanding on Dec. 31st, 1880, has been increased by more than £100 during the year, standing at £230 16s. 6d., instead of £129 10s. 3d. as in the accounts for 1879.

"It is true that the sale of the Magazine has produced £40 6s. during the year 1880, whereas only £15 8s. was realised from the same source in 1879. The Council may, therefore, assure the members that they have put down the value of the stock in hand of the Magazine at a very low estimate (one third of its selling price) when they have entered £185 for this item as a set off against the printer's account.

"They have, however, deemed it advisable to restrict, temporarily, the issue of the successive parts of the Magazine, and, accordingly, only three instead of four parts have appeared since the last Annual Meeting; viz., No. 18 in Sep. 1880, No. 19 in April, and No. 20 in August 1881.

"They determined in December last that the price of the yearly series of the Magazine shall be at least equal to the amount of the yearly subscription of the Members.

"By a continuance of judicious economy in the department of printing, the Council feel confident that they will be able to replace the Society in a satisfactory financial position, as a considerable sum has been paid to the printers during 1881, and the amount due to them, after the issue of Part 20, is only £153 12s. 1d., while the cash in hand is £74 15s. 9d., and the outstanding bills, exclusive of printing the Magazine, do not exceed £6.

"The chief contributor to the Magazine has been our President, whose paper on "The Geognosy and Mineralogy of Sutherland," in continuation of its predecessors on Shetland, Orkney, and Caithness, occupies the greater part of two of the numbers which have appeared during the year.

"As soon as this paper is completed, a geological map of the county will be issued, which has been drawn by Prof. Heddle upon a map prepared from original survey and engraved for the Duke of Sutherland, K.G. The Council are in a position to say that this map, which will be sold to non-members at the price of a guinea, will be distributed to the actual Members and Associates at the time of its appearance *gratis*, as a part of the Magazine.

"The only other paper calling for special notice has been a further contribution from Mr. Collins "On Cornish Tinstones and Tin Capels," which appeared in Part 18.

"In conclusion, the Council have to report that the Society has sustained a severe loss in the resignation by Mr. J. H. Collins of the combined offices of General Secretary and Editor of the Magazine, which he has filled with such advantage to the Society ever since it was first founded in 1876.

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"It was mainly by Mr. Collins' efforts that the Society was brought into being, and it is to his untiring energy that its present position is almost exclusively due. His resignation became inevitable owing to his acceptance of a post connected with the Rio Tinto Mines in Spain, which necessitated his residence out of England. The Council have as a temporary measure requested Mr. R. H. Scott to act as General Secretary for the present, and have entrusted the editorial functions to a committee of five Members, including the President and General Secretary."

(Signed) M. F. Heddle, President.

The President then called on Mr. Greg to move his proposed change in Rule 17, of which notice had been duly given.

Mr. Greg proposed and Mr. Sorby seconded the following alteration of Rule 17.

"At meetings of the Council three shall be a quorum, of whom one shall be either the President, one of the Vice-Presidents, or the General Secretary."

The alteration was put to the vote and carried unanimously.

The President proposed, and Mr. Dudgeon seconded the following addition to Rule 24.

"All expenses incurred at local meetings are to be defrayed by the Members who take part therein."

This addition was also carried unanimously.

Mr. Scott proposed, and Mr. Walker seconded the following addition to Rule 31.

"The name of any Member or Associate whose subscription is more than three years in arrear shall, after intimation to said Member, be erased from the list of the Society, but the person expelled shall have a right of appeal, as provided by Rule 28."

This addition was also carried unanimously.

The General Secretary then read a paper by Prof. A. Liversidge "On a peculiar copper ore from Coombing Copper Mine, New South Wales."

The President and other Members expressed their agreement with the Author of the paper that the substance was not a specific ore but only a mixture, and Dr. Trechmann pointed out that if so much silica was present as had been found the mineral should be translucent in thin slices.

Mr. P. Dudgeon read a paper "On the occurrence of 'Linarite' in Slag."

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Mr. Sorby pointed out the very great interest which attached to the discovery of minerals formed under conditions of which we knew something, such as those found in furnace products.

Mr. I'Anson read a joint paper by himself and Mr. E. A. Pankhurst "On Artificial forms of Silica," illustrated by a series of preparations.

The President stated that he considered the paper to be one of the most interesting he had heard for a long time. He himself had studied Agates for many years, and he possessed a collection of over 5000 specimens. His friend, Mr. Dudgeon, had also a very large collection.

The paper gave rise to considerable discussion, and Dr. W. Lant Carpenter stated that he had produced a deposit of Silica of considerable hardness by precipitation from an Alkaline Silicate.

Dr. Trechmann read a preliminary "Note on a new occurrence of Epistilbite."

The General Secretary read a note by Mr. W. Terrill "On Artificial Crystals of Specular Iron, found in a Copper works Slag."

EXCERPT MINUTES OF COUNCIL MEETING,

Held at 116, *Victoria Street*, *Dec.* 14*th*, 1881.

W. H. Hudleston, Esq., F.G.S., President, in the Chair.

The following gentlemen were duly elected Members.

H. Baker, Esq., F.C.S., Manchester,
R. Fleming, Esq., 1, Exchange Place, Dundee.

Resolved—"That the Geological Map of Sutherlandshire, prepared by Professor Heddle, be issued as part 21 of the Magazine."

A GENERAL MEETING OF THE SOCIETY

Was held on Wednesday, December 14*th*, 1881, *at* 116, *Victoria Street*, *at* 8 *p.m.*

W. H. Hudleston, F.G.S., President, in the Chair. 9 Members were present.

The minutes of the Annual General Meeting at York, Sept. 2nd, were read and confirmed.

The Secretary read the following paper "On some minerals from the Sodalite Syenite of Julianshaab District, South Greenland," by Johann Lorenzen, Communicated by Prof. Johnstrup (Foreign Member).

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The President announced that two visitors were present from the Kimberley Mine, South Africa, Messrs. E. Baring Gould and Porter Rhodes, and he invited them to give an account of the working of the mine.

Mr. Porter Rhodes exhibited a model of his Great Diamond, weight 152 carats, and several specimens of diamonds, as well as of the "reef," the diamantiferous matrix, with crystals imbedded in it.

Mr. Baring Gould exhibited photographs of the workings of the mine.

An interesting conversation ensued, and the President in closing the meeting expressed the warm thanks of the Society to their visitors of the evening, for the very interesting communication they had made.

Mr. Rudler exhibited a specimen of native copper from the sinter of a geyser in Iceland.

EXCERPT MINUTES OF COUNCIL MEETING.

Held at 166, *Victoria Street, March* 23*rd*, 1882.

W. H. Hudleston, F.G.S., President, in the Chair.

The audited Balance Sheet for the past year was submitted, and ordered to be printed for distribution to the Members.

The following gentlemen were duly elected Members.

Alexander Davidson, Esq., Fergus Place, Kirkcaldy, Fifeshire.
Ridley Henderson, Esq., 9, Bush Lane, Cannon Street, E.C.
Alexander Hutton, Esq., Royal Bank, Arbroath.
Colin Livingston, Esq., Fort William, N.B.
George Tate, Ph. D., F.G.S., College of Chemistry, Liverpool.

ASSOCIATE:

H. F. Collins, Esq., Royal School of Mines.

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Abstract of Receipts and Payments of the Mineralogical Society, for the Year 1881.

RECEIPTS.

Dr.	£	s.	d.
Balance on January 1st, 1881	42	4	3
Subscr ptions for 1882	5	10	0
——— ——— 1881	90	18	0
——— ——— previous years	31	15	0
Life Compositions (7)	73	10	0
Entrance Fees	17	17	0
Sale of Publications (exclusive of Publisher's Sale) ...	12	19	2
Dividends and other small items	3	6	11
	£278	0	4

PAYMENTS.

Cr.	£	s.	d.
Printing and Illustrations...	199	12	6
Expenses incidental to Meetings	0	7	6
Clerical Expenses...	6	17	6
Postage and Parcels	10	13	9
Investments	51	11	11
Sundry small items	3	8	6
Balance in hand and at Bank	5	8	8
	£278	0	4

March 6th, 1882.

Examined and found correct. BENEDICT KITTO. F. W. RUDLER.

LIABILITIES.

	£	s.	d.
Lake & Lake, Printing	121	1	3
Wightman & Co., Printing	1	19	0
Heard & Son, Printing	0	13	0
Subscriptions paid in advance	5	10	0
Excess of Assets over Liabilities	111	14	4
	£240	17	7

ASSETS.

	£	s.	d.
Subscriptions for 1881, unpaid	22	15	0
——— ——— prior to 1881, ———	12	12	0
New Three per Cent. Annuities, at Par	136	12	3
Stock of Publications, valued at average Annual Sale	36	19	0
Publications sold by Publishers (amount unpaid) ...	26	10	8
Cash at Bank	0	17	4
Petty Cash in hand	4	11	4
	£240	17	7

Signed { BENEDICT KITTO. F. W. RUDLER.

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

No. 22 FEBRUARY, 1882. Vol. V.

I.—*Minerals New to Britain.*

By Professor Heddle.

Read December 23rd, 1880.

A NUMBER of minerals not before noticed as occurring in Britain have been described, and corroborative analyses thereof have been given, in the papers which I have, from time to time, published in the *Transactions of the Royal Society of Edinburgh*, and also, though to a smaller extent, in the *Mineralogical Magazine*.

Those which I now bring forward, have been analysed for the most part for a considerable time; but, as it must of necessity be long before I come to notice them, in their proper place, in my "Geognosy of Scotland," it is well to announce their occurrence without further delay.

Halloysite.

This was found in the Hospital Quarry, near Elgin, by Professor Nicol, and sent to me by him, as a substance which he could not recognise. As my own experience did not avail in determining it, the specimen was analysed.

Prof. Nicol obtained it in a vein of an inch and a half in thickness.

The colour is white to faint yellow, it is very soft and friable, with a minutely-granular structure.

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It yielded—

Silica	39·300
Alumina	38·572
Ferric Oxide	1·428
Manganous Oxide	·250
Lime	·746
Magnesia	·833
Water	19·340
	100·469

It loses 4·626 of the above water at 212°.

This quarry was afterwards visited by Professor Nicol, Mr. Dudgeon, and myself, under the guidance of Dr. Gordon, of Birnie; when the mineral was found in a very singular and interesting position.

On the north cliff of the quarry, in a now unworked portion thereof, there is a rent of about a couple of feet in width; this rent extends downward through the stratum to a greater depth than the working has been carried.

The rent has been filled to a depth of over thirty feet by boulder clay. At about five and twenty feet from the surface, we found the mineral in the boulder clay, disposed in granules, clotted-like masses, and threads. There could be no question that it was a product of change.

Imbedded portions of clay-like substances, of an obscurely fissile structure,—doubtless altered fragments of schists,—were also found imbedded in the sandstone of the quarry. These, upon analysis, yielded a composition which pointed to no evident formula of expression.

Fibrolite.

I found this mineral, in small quantity, coating gneiss, in thin veins on the north-west side of Pressendye Hill, in Aberdeenshire; at about 300 yards from the summit of the hill.

Its colour was white; it was in fibrous tufts, which were very tough. No piece was got large enough for ascertaining the specific gravity.

It yielded—

Silica	39·680
Alumina	58·822
Ferrous Oxide	·038
Manganous Oxide	1·100
Potash	·860
Soda	tr.
Water	·320
	100·820

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I have also found the mineral in much larger quantity, on Clashnaree Hill, in Clova, associated with *red andalusite* and *black mica;* but have failed to pick it out pure enough for analysis.

Here it is in parallel acicular crystals, which are highly lustrous, and it seemed to pass into the red andalusite.

Martite.

This was given me by Professor Archer, as having been found on the sea shore, on the north-west of the island of Bute.

The parcel consisted of rolled octahedral crystals; many of these had a red colour, and a loose and soft structure; the largest proportion, however, occurred in hard blue-black lustrous crystals, a very few of which were feebly magnetic. The majority of the crystals were entirely destitute of magnetism.

The powder was red; but in other respects the mineral seemed to be unchanged *magnetite;* the hardness and gravity being normal.

The blue-black crystals were analysed and yielded—

Ferric Oxide	97·049
Ferrous Oxide	1·096
Manganous Oxide..	·200
Lime	·952
Silica	·700
	99.997

There was no trace of titanic acid. Martite would thus appear to be in some cases merely altered magnetite.

Turgite.

This I found in isolated, imbedded, cubic crystals, in clay slate, in the Island of Kerrera, in Argyllshire; and also to the east of Oban.

These crystals have invariably a hollow in their centres: they are red-brown, and stain the hands of the same colour.

As imbedded *pyrite* occurs in the same rock, in their vicinity, they undoubtedly have resulted from its alteration.

Their specific gravity is 3·534. They yielded—

Ferric Oxide	86·585
Lime	·818
Water	5·559
Silica	7·692
	100·654

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Xonaltite.

This was first found by Mr. Rose and myself, along with *gyrolite*, near Kilfinnichan, Loch Screden, Mull. More lately it was found by myself at Gribon, opposite Oronsay; and also on the north shore of Loch na Keal, in the same island.

At both of these places, it resembles a granular pink chalcedony. Its specific gravity is 2·605; it is generally associated with gyrolite, the plates of which are nearest to and radiate from the surface of the rock; they thus penetrate, as it were, the substance of the massive-looking *xonaltite*, which appears as if it had been poured over them.

It yielded—

Silica	48·910
Alumina..	·111
Ferrous Oxide	2·966
Manganous Oxide	2·270
Lime	40·385
Magnesia	·559
Potash	1·164
Soda	·222
Water	4·173
	100·760

The occurrence, as British species, of the rocks and minerals which now follow, has been before noted; but, so far as I know, no analyses of these have been published.

Schiller Spar.

I found this mineral first in the immediate neighbourhood of Aberdeen. There is to be observed in the long sand-beach which stretches from Aberdeen to Forvie Ness, at the distance of about four miles from the town, a mass of rock, which, from some fancied resemblance, has received the name of "the Black Dog." This consists of crystals of *talc*, matted in such confusion as to form both a tough and a hard rock.

A little seaward of this, there lie, impacted in the sand, and submerged at high water, two very dark masses. The three, occurring in line, point to the little Burn of the Black Dog. The banks of this burn indicate that a vein of similar material may have been lodged in it. This vein may run to the large mass of serpentine which occurs in the neighbourhood of Belhel , as mentioned below.

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The black masses, when broken into, proved to be a mixture of a dark *serpentine*, with crystalline lumps of the mineral in question.

These crystalline lumps cleaved uniformly in one direction;—they had no trace of definite external form.

In appearance they in every way were identical with the Basta specimens,—being, however, markedly larger in the glimmering foliations.

Their specific gravity was 2·649. The portion analysed was as much as possible freed from the dark serpentinous *rods* which penetrate the mineral in so singular a manner; but, at the best, this could be effected to but a small extent. It need hardly be said that the portion chosen was one in which the green glimmering matter predominated.

The analysis was conducted on 1·092 grammes, and yielded:—

Silica	38·186
Alumina	2·178
Sesquioxide of Chromium	·276
Ferric Oxide	·028
Ferrous Oxide	8·479
Manganous Oxide	·513
Lime	2·912
Magnesia	32·418
Potash	1·401
Soda	·065
Water	14·030
	100·486

Of the Silica, 5·914 per cent was insoluble in boiling sodium carbonate.

Shortly after having discovered the mineral at this locality, it was found by Professor Nicol and myself, in two quarries which are cut into a hill-side near the farms of Craigie and White-Cairns, on the west side of the Belhelvie Hills. We were guided to these quarries, first by the blackness of the road-metalling, and then by being startled by seeing what we took for *buttons of bronze*, lying among the dark and ground-up metal of the road. These bronzy buttons proved to be slightly weathered and loose lying crystals of *schiller-spar*. Even in the quarry they are not so unaltered as those which, upon the sands at the Black Dog rock, were shut off from the air by the sea water.

Native gold has been said to occur in serpentine in this neighbourhood; the occurrence here of *pyrite* in dendritic forms, and of a surprisingly golden tint, doubtless accounts for the assertion.

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It will be seen from the above analysis, that this substance is very much of the nature of a serpentine; or perhaps it would be more correct to say that it is an apparent passage of an enstatitic mineral into serpentine; like the so-called *bronzite* of Balhammie Hill, an analysis of which I have given elsewhere.

Indeed, a section of this Schiller-spar shows, under the microscope, *processes* of serpentine extending from the serpentine rods; these processes branch and anastomose, so as, in parts of the slide, almost to usurp the whole ground of the transparent mineral.

Hydrous Saussurite.

The late Mr. David Forbes has stated that Saussurite is a common mineral in Scotland. While there are certain of the massive granular *labradorites*, or mixtures of *labradorite* with *anorthite*, which bear some resemblance to the Saussurite of the Geneva blocks, I have never by analysis been able to prove the existence of true Saussurite in Scotland.

The substance which bears most resemblance to it, is an opaque, white, minutely-granular substance, which, along with large crystals of diallage, forms the "*diallage rock*" which occurs upon the shore, a little northward of Lendalfoot, in Ayrshire.

This substance has a greasy lustre, and is exceedingly tough. It has no cleavage. The specific gravity is 3·088.

Its analysis yielded:—

Silica	39·923
Alumina	27·511
Ferric Oxide	1·918
Lime	17·126
Magnesia	1·663
Potash	1·395
Soda	4·626
Water	6·124
	100·186

This looks somewhat like a hydrated Saussurite; but the following fact throws much doubt upon the correctness of such an inference.

Grey striated crystals of *anorthite* also occur in association with the diallage at the same locality. These have a specific gravity of 2·761.

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Well marked crystals of this mineral yielded:—

Silica	44·224
Alumina	31·442
Ferric Oxide	1·955
Lime	14·180
Magnesia	1·000
Potash	1·480
Soda	1·625
Water	4·023—3·348
	99·929

The crystals chosen for analysis were taken as being quite apart from any contact, or mixture, with the former mineral. But, where the larger masses of the first analysed mineral occur, they are, when broken up, almost always found to contain a more translucent and distinctly-striated *centre of anorthite*,—which latter *passes by insensible gradation into the so-called Saussurite.*

This would lead to the conclusion that the sea water had effected the change; a conclusion which, however, hardly can account for the marked increase of specific gravity.

The fact of the occurrence of *Prehnite*, (a mineral with a very similar composition,) in the immediate neighbourhood, scarcely, in the present state of our knowledge, aids in explaining the relationship.

The Prehnite—(which has been analysed) and which occurs in crystals, is found to form the white bands of a highly-convoluted and much-altered schistose rock; one which, in its denser and more altered portions, somewhat simulates an igneous one.

Though the district has been examined by more than one eminent geologist, it calls for a very much more careful examination than it has received: and this examination will fall far short of perfection if it be not supported by, or based upon an extensive series of analyses. While I do not adopt Dana's view that true Saussurite is allied to *zoisite*, I also hesitate to assign the present mineral to Saussurite; and have given it the above qualified name, merely to direct attention to it, and to the interesting circumstances of its occurrence.

Tachylite.

This was found as a crust of about half-an-inch in thickness, upon the under surface of one of the beds of amygdaloid which occur in the approach to the Quiraing in Skye,—near the summit of that approach. The dolerite was itself dense and close grained. The

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tachylite appeared to be the result of the fusion of the dolerite, or perhaps of its rapid chilling when first poured out; there being a passage of structure at the point of contact.

The tachylite was in parts dark-brownish-black, and it was then lustrous. More usually it was black, or pitchy brown; then its lustre

Ferric Oxide	5·027
Ferrous Oxide	9·022
Manganous Oxide..	n. d.
Lime	8·104
Magnesia	3·820
Potash	2·000
Soda	3·820
Water	7·222
	99·448

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The change is thus very slight. The portion which has fused is slightly more alkaline; and, from its retention of water, it must have liquified under great pressure.

Pitchstone.

From Corrieghil, Arran. This is the dark brown-black *pitchstone* which, with imbedded transparent crystals of colourless *sanidine*, forms the well known and beautiful porphyry of this locality.

It yielded—

Silica	72·066
Alumina	11·263
Ferric Oxide	3·237
Manganous Oxide	·002
Lime	1·530
Magnesia	·003
Potash	5·612
Soda	·605
Water	5·449
	99·767

Spherulite.

From the pitchstone of Corrieghil, Arran. It occurs in the paler green varieties of the pitchstone. Where this weathers, it exhibits a spherical structure on its surface; which seems to show that the spherical portions of the rocks are less soluble in water, than the amorphous. When broken, the imbedded spherules are seen to have a radiated structure, cinctured now and again with one which is concentric. The concentric bands are sometimes white and powdery.

Silica	77·230
Alumina	10·440
Ferric Oxide	1·867
Manganous Oxide	·538
Lime	·904
Potash	5·740
Soda	2·225
Water	1·186
	100·130

It loses ·342 per cent. of water at 212°. Taking into consideration this larger proportion of silica,—along with the radiating structure and its more sparing solubility, it would appear that this is a pitchstone which contains bundles of radiating crystals of quartz, or perchance *tridymite*.

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Paulite.

"*Hypersthene*" has, or rather *had* been for long considered to occur among the Coolin Hills of Skye.

My analyses of specimens, furnished by those who most strongly maintained its existence there,—which analyses were published in the *Transactions of the Royal Society of Edinburgh*,*—proved that the mineral supposed to be hypersthene, was *augite*.

The mineral had, however, been said also to occur in the neighbourhood of Portsoy, in Banffshire. This I find by analysis to be correct. It occurs, somewhat ill-defined, in some veins or beds,—it is difficult to say which,—of diorite, on the west shore of the East Bay of Portsoy. But, in company with Mr. Peyton, I have found it to occur in much finer specimens in the loose masses of a wasted outcrop, on the west side of Craig Buroch, in the same county; while again Mr. Peyton had himself previously found it, in still finer specimens, south of the farmhouse of Retannach, in the same neighbourhood. Here also it occurred in loose blocks. The blocks on Craig Buroch lie in line, and indicate the weathered outcrop of a bed.

In these blocks it occurs in what are probably exfiltration-veins; and its immediate associates are, striated grey *labradorite*, massive *iserine*, *pyrite*, and an *augite*, which much resembles *enstatite*.

The colour of the Paulite is bronzy, with a shade of red-purple on one cleavage; it is black and lustreless at right angles to this. The cleavage was as figured—*b* being the lustrous face; *a* the black. It had a lustre quite as brilliant as have the Newfoundland specimens. Its specific gravity is 3·32; its powder is light-brown.

1·3 grammes yielded—

Silica	51·461
Ferric Oxide	4·022
Ferrous Oxide	12·673
Manganous Oxide	·692
Lime	5·299
Magnesia	24·230
Potash	·252
Soda	·741
Water	·519
	99·889

It loses at 212°, ·436 per cent. of water.

* Vol. XXVIII, p. 478.

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The *Paulite* both of Retannach and of the East Bay of Portsoy, seems to pass into the glassy bottle-green enstatite-like variety of augite. I considered this bottle-green mineral to be enstatite until it was analysed. Its analysis is published in the *Transactions of the Royal Society of Edinburgh, Vol. XXVIII, p.* 465.

In polished slabs of the rock from Portsoy, the bronzy flash of Paulite is seen surrounding the translucent green mineral like a fringe. Sections of the Retannach augite, again, are bronzy in spots; and these spots the microscope shows to be "shot" more or less profusely by the characteristic flattened-tube structure of the Paulite.

Zoisite.

This has been stated by Jameson to occur at Glenelg. From its occurrence at several other limestone localities in Scotland, this is far from improbable; but I have not myself, during several visits, succeeded in finding it there.

A specimen moreover, from this locality, which was given to me for analysis by Principal Forbes, as Jameson's Zoisite, proved to be malacolite; it was in a lanceolate form, one in which I have there found that mineral in abundance.

1. I first found Zoisite in Scotland in a quartzose bed in the limestone at Gartally, in Glen Urquhart. It occurs in colourless and grey crystals, imbedded either in horny quartz, or in the lime itself.

Its specific gravity is 3·014. It yielded

Silica	39·600
Alumina	31·083
Ferrous Oxide	2·071
Manganous Oxide	·078
Lime	23·336
Magnesia	tr.
Potash	·566
Soda	1·056
Water	2·412
	100·202

2. This specimen was given me by Professor Geikie. It was got in a limestone quarry on a hill side about half-a-mile west of Laggan, Dulnan-Bridge, near Grantown, Invernesshire.

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It here occurs in pale brown crystals imbedded in a bed of translucent, but muddy quartz. On visiting the locality, I found that it is associated immediately with *chlorite*, *sahlite*, *Biotite*, and other minerals occuring in limestone. In the near neighbourhood are found *kyanite*, also small quantities of *galena* and *blende*.

The specific gravity of the Zoisite is 3·438. It yielded—

Silica	38·750
Alumina..	28·144
Ferric Oxide	6·547
Manganous Oxide	·916
Lime	22·026
Magnesia	·416
Water	3·333
	100·132

It loses ·155 per cent. of moisture at 212.°

Idocrase.

The specimen analysed was part of a magnificent dark-brown crystal of nearly seven inches in length by one in thickness,—unfortunately broken in the extraction, or rather in the discovery,—which was got in the limestone quarry of Dalnabo, in Glengairn, Aberdeenshire.

Its specific gravity is 3·43. There was obtained—

Silica	36·251
Alumina..	18·626
Ferric Oxide	·932
Ferrous Oxide	5·036
Manganous Oxide..	·844
Lime	33·935
Magnesia	1·574
Potash	·568
Soda	·529
Water	1·780
	99·875

The Idocrase is associated with so large a number of minerals, that it is a source of great regret that the quarry is no longer worked.

Andalusite.

Red andalusite—formerly called "red schorl," has for long been known as occurring in Aberdeenshire; and Achindoir has been given as the locality.

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The late Rev. Mr. Morgan, of Stonehaven, undoubtedly found the locality; but he kept it a close secret. It took the writer many wanderings, during part of three summers, before he found the place.

This is the southern slopes of the hill of Clashnaree in Clova;—and also in small amount on the south side of the Peat Hill.

The specimens all lie loose; being fragments of veins which have endured, after the disintegration of a very micaceous gneiss.

The mineral very rarely is crystallised in distinct forms; being frequently bacillary. Its associates are *labradorite*, *fibrolite*, and an ill-defined *black mica*.

Its colour is a dull but uniform red;—occasionally the central core is purple.

Its specific gravity is 3·121.

The analysis, on 1·302 grammes, yielded

Silica	36·712
Alumina..	59·678
Ferric Oxide	2·302
Manganous Oxide	·230
Lime	·860
Magnesia	tr.
Water	·465
	100·247

Not unfrequently it passes directly into fibrous white *fibrolite*.

2. This variety was found in the banks of the stream, near the Mill of Auchintoul, Kinnairdy Castle, Marnoch, Banffshire.

It occurs in imbedded crystals of half-an-inch in length, along with small twin crystals of brown *grenatite*: the matrix is a scaly micaceous schist. Specks of magnetite are also present. Water-friction having removed the more friable mica, the imbedded crystals are frequently left protruding. The crystals are ash-grey; of a vitreous lustre; and hardly touched by the knife; in parts not at all so. They contain, imbedded in their mass, apparently only a minute quantity of the matrix. The angle of the crystals is *near* a right angle.

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There was obtained, from very carefully picked crystals—

Silica	52·538
Alumina..	39·314
Ferric Oxide	1·094
Ferrous Oxide	3·267
Manganous Oxide	·461
Lime	·861
Magnesia	·846
Alkalies	tr.
Water	1·110
	99·491

It is thus evident that much of the matrix pervades these crystals throughout.

This locality was found by the Rev. Mr. Peyton.

The bed of schist which carries these crystals is seen, to the northward, a little east of the village of White Mills; it courses up the country, southward to the Coreen Hill, near Lumsden in Aberdeenshire. In Marnoch the rock has been used for mill-stones; at Lumsden it is utilised for pavements. The intensely hard crystals of andalusite in both cases, protrude from the general surface of the stone; they act in the first case as grinding teeth; in the second, they admirably prevent slipping.

Besides the bed which crops out on the shore near White Mills, other smaller ones are seen along the same shore; some of these—notably one near Banff—exhibit small concretions of a colour either darker or lighter than the general mass of the rock; and, as many of the crystals in the Clova district have a form as undefined or ill-defined as these concretions, I incline to regard the latter as being probably an interrupted stage in the formation of the crystals of the mineral.

The analysis would indicate that nowhere in this district has the crystalline force succeeded in absolutely excluding the rock matrix; though there is not here, or at least in this deposit, that definitiveness in the mode of its exclusion, or rather *extrusion*, which produces *chiastolite*. *That* mineral however occurs in a bed of clay slate, a little west of Portsoy. It should also be noted that most of the crystals at White Mills, are converted into a steatitic material of a purple colour; the varying depth of which exhibits the *chiastolite*

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arrangement of particles: so that it may be said that in this district, both the *segregatory formation*, and the *decay* of this mineral is to be seen.

At the head of Glen Creran on its west side, in Glen Nevis, and near Cuil Bay, in Appin, I have also seen a rock which seems to contain incipient crystallisations of andalusite.

Withamite.

From Glencoe. The specimens, before the picking, showed minute traces of quartz, and sometimes a surrounding layer of a white dull substance; this was thought by Allan to be *Saussurite*.

The associated minerals were *green epidote*, a granular green mineral like *chlorite*, but which was probably *Delessite*, silky colourless *byssolite*, and, in the near neighbourhood, a single specimen of *Wavellite* was found.

The picking was executed with the most extreme care,—only crystalline portions being taken.

There was got—

Silica	43·230
Alumina	23·090
Ferric Oxide	6·675
Ferrous Oxide	1·131
Manganous Oxide	·138
Lime	20·003
Magnesia	·884
Potash	·962
Soda	·935
Lithia	·253
Water	2·400
	99·701

This does not agree over well with epidote, to which *Withamite* is always assigned; but the measured angles of the crystals leave little doubt as to its being a variety of that mineral. It is strongely dichroic; showing carmine, and straw yellow.

Olivine.

From columnar basalt at Shooter's point, Elie, Fife.

It occurs in large imbedded masses—a couple of inches in diameter,—associated with *pyrope*.

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These masses are sometimes rudely crystalline; they are much fissured, of a vitreous lustre, and an apple green colour.

The specific gravity is 3·327. I obtained—

Silica	42·615
Alumina..	3·154
Ferric Oxide	2·965
Ferrous Oxide	6·261
Manganous Oxide..	·230
Lime	4·436
Magnesia	36·692
Potash	1·072
Soda	1·483
Water	1·164
	100·072

2. Was found near the summit of Halival, and more rarely on Hæskheval in Rum.

It occurs in badly developed crystals, in the "augite rock," along with glassy green *augite* and *labradorite*. The colour is yellow, and slightly brownish. The lustre is vitreous. Frequently there is slight decomposition, the much flawed crystals becoming powdery and dull. The powder is earthy, and of much the same colour as the unaltered mineral.

The crystals are sometimes imbedded in those of the augite,—more commonly they lie side by side. Their general appearance is somewhat like that of chondrodite.

They yielded—

Silica	38·006
Alumina..	·286
Ferric Oxide	2·933
Ferrous Oxide	18·703
Manganous Oxide..	·100
Lime	·336
Magnesia	38·000
Water	1·587
	99·945

The specimen analysed was not *absolutely* free from the powdery portion: the ferric oxide may represent the change to some extent. That change in no way resembled a passage into serpentine: indeed it has to be remarked that the mineral itself does not resemble olivine; while the associated glassy augite very much resembles it.

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Pinite.

This mineral has been noted by Dr. Macculloch as occurring in certain porphyries which cut the quartzite of the Cairnwell hills in Perthshire; he also notes it as actually imbedded in quartzite, west of Ben y Gloe. I will not say that the mineral he observed was not something of this nature:—it is in small six-sided prisms,—but these are distinctly foliated, and they always appeared to me more like a black mica which was somewhat decomposed.

I have myself noticed a substance very similar to these crystals, and which bore much more resemblance to *pinite*, in the red porphyry which is interstratified with the quartzite of Canisp, in Sutherland.

The substance I at present note, however, is not to be mistaken,—though its colour is somewhat unusual for pinite. It occurs imbedded in micaceous gneiss in the banks of a stream—the Burn of Craig,—on the north-east slopes of the Buck of the Cabrach, in Aberdeenshire. It is associated with *Biotite* (*or* lepidomelane).

It is crystallised in prisms of about an inch in width, and passes into *chlorophyllite*; its colour is asparagus green, it is transparent, and of vitreous lustre. Its appearance is intermediate between *apatite* and *beryl;* and it is altogether very gem like.

Its specific gravity is 2·911. ·98 grammes yielded—

Silica	41·224
Alumina	28·498
Ferric Oxide	·156
Ferrous Oxide	5·484
Manganous Oxide	·102
Lime	·914
Magnesia	6·612
Potash	10·367
Soda	·953
Water	5·670
	99·980

Of the silica only ·198 per cent. were insoluble in sodium carbonate solution.

Gigantolite.

This was first given me by the Revd. Mr. Peters, of Deer, through Mr. Alexander Cruickshank, as from Torry, Aberdeen. In 1877 it was obtained by myself, along with the last named gentleman and Professor Nicol,—in a granitic vein, a little east of the remains of the old breakwater at Torry. It was associated with *Davidsonite* (beryl) *specular iron, muscovite* and *tourmaline.*

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The *gigantolite* or *iberite* occurs in crystals of an inch in width, by two in length; the form is generally obscure, having frequently as much resemblance to that of tourmaline as to *iolite*. The colour at the deeper-seated end is dark green; the structure minutely foliated and dense. At the other extremity of the crystals, the material is almost wholly apparently *muscovite;* arranged as a matted mass of somewhat loosely-coherent crystals.

The specific gravity of the dark dense substance analysed, was 2·898. 1·3 grammes yielded—

Silica	41·307
Alumina	28·709
Ferric Oxide	14·175
Manganous Oxide	1·000
Lime	·473
Magnesia	2·615
Potash	6·560
Soda	1·642
Water	4·250
	100·231

The possible impurity here was *mica*.

Chlorophyllite.

I found this in a deep cutting in the banks of the head-stream of the Burn of Craig, about one mile north-east of the Buck of the Cabrach, in Aberdeenshire. It was associated with *Lepidomelane* (?), and it contained, in the centre of some of its crystals, unaltered *pinite*. It was in crystals of an inch in size. Its colour was green, slightly brownish in parts; lustre somewhat pearly; opaque; it was softer than the pinite. It was precisely similar to the American *chlorophyllite*. Specific gravity 2·715.

Silica	41·266
Alumina	28·881
Ferrous Oxide	5·207
Manganous Oxide	·333
Lime	·858
Magnesia	6·633
Potash	10·083
Soda	1·406
Water	5·812
	100·479

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There is thus very little difference between it and the *pinite* which it enveloped, and of which it seemed to be but an alteration product.

Scapolite.

Many years ago, while compiling his work on British Minerals, Greg wrote to me, expressing his surprise that a mineral so common elsewhere as scapolite, had never been found in Britain.

Some time after this Dr. Lauder Lindsay reported on the occurrence of a crystallised scapolite, in association with a hornblendic mineral, near lime, in the vicinity of Loch Callater, in Aberdeenshire. These crystals, however, on examination proved to be malacolite.

Again, in a report on the Granites of Donegal, submitted to the British Association by Mr. Robert H. Scott, Sir R. Griffith, and the Rev. Dr. Haughton, it is stated that in almost all the limestone localities, they found a peculiar rock, which, from the great abundance of that substance, they turned "sphene rock." "It consists of orthoclase, green pyroxene, and quartz; and in it we have discovered minute crystals of blue apatite; and in one locality (Glenleheen) a great abundance of white Scapolite." The precise locality is afterwards stated to be the cross roads, in Glenleheen; and it is also stated to occur at Tirlyn. Mr. Scott has kindly forwarded to me a specimen of the Glenleheen mineral, with the remark, "on a closer examination I think it is like a felspar."

The specimen consists of crystals of over half an inch in size, imbedded singly in quartz. These crystals have a rectangular section, and almost a pearly lustre. They are cream coloured, with a cleavage which is at least *nearly* a right angle. Here and there they seem to be striated. They have much the look of a felspar; but the fact that some of the imbedded rectangular crystals present a lustrous cleavage face, which is *also* apparently nearly at right angles *to the other two*, must throw doubt upon this conclusion.

Having no authority to detach any portion for measurement or examination, I am able to say no more than that these crystals cannot be *scapolite*, and in general appearance much resemble *albite*.

It is only within the last few years that I have found this mineral in Scotland; and on both of the occasions in which I have done so, it was a "chance find."

1. Making a habit of examining fully, and, if there be a sufficiency, of analysing every substance which I am unable satisfactorily to recog-

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nise, I set apart for examination a rough crystal, which I worked out of the limestone which occurs about a mile north-east of Milltown, in Glen Urquhart, Rosshire.

This rough crystal was imbedded among the *Zoisite* which is there found. It occurred in what I am unable to designate more precisely than *the central of the many quarries* which have been opened in the highly convoluted stratum of limestone.

It was a greyish coloured translucent crystal; and, being imbedded, no form could be made out. It was separated from the *zoisite* and set apart for examination, on account of its being of a greyer tint; and was suspected to be *andesine*,—*scapolite* not having been thought of.

It was very slightly mixed with pale-green *actynolite*,—say $\frac{1}{200}$th part;—and this may not have been absolutely separated from the portion analysed. Its specific gravity is 3·004.

Quantity analysed 1·305 grammes.

Silica	45·900
Alumina	27·369
Ferric Oxide	tr.
Ferrous Oxide	2·954
Lime	20·211
Magnesia	·306
Potash	·315
Soda	·582
Water	2·089
	99·728

4·34 per cent. of the silica was insoluble in boiling sodium-carbonate.

I know not whether to rank this with *scapolite* or with *paranthine*.

2. In dissolving the Tiree marble, in order to obtain the *tireeite* described in a late number of the Magazine, I obtained a very large quantity of crystals of *sahlite*. From out of many pounds of these crystals, I picked about 100 grains of fairly-well developed crystals of a pure white, and pinkish-white mineral. Though the angles of the secrystals were,—like those of the *sahlite* and *sphene*, which occur in this limestone,—rounded, yet the form of *scapolite* was easily made out. The square prism had its lateral angles truncated;—and there was a four-sided pyramid. The crystals were of the size of large shot. The only other substance which accompanied these crystals was *talc*, in minute flakes.

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1·3 grammes yielded.

Silica	48·923
Alumina	22·098
Ferric Oxide	3·159
Ferrous Oxide	1·508
Manganous Oxide	·538
Lime	7·753
Magnesia	2·769
Potash	6·058
Soda	1·279
Water	5·694
	99·779

Loses at 212°, ·972 per cent. of water. 2·358 per cent. of the silica was insoluble in boiling solution of sodium-carbonate.

Pyrrhotite.

From a limestone quarry about 200 yards south-west of Fiermore, south of Tullich Hill, Blair Athole. Occurs in lumps in the vein-stone of the lime, associated with *chlorite*, *sphene* and *ilmenite*.

I obtained:

Sulphur	38·544
Iron	60·300
Silica	·153
Carbonate of lime	1·538
	100·695

Though the lime is here given as in combination with carbonic acid, as the probable form of combination, yet not the smallest trace of effervescence could be seen when acid was added to the crushed mineral.

Pyromorphite.

The specimen examined was the bright orange, or so called "chromo-phosphate of lead," from Leadhills. It was in well developed hexagonal crystals,—quite free from matrix or any impurity.

There was obtained:

Phosphate of Lead	89·038
Chloride of Lead	10·477
Phosphate of Iron	·447
	99·892

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The colour would seem to be due to phosphate of iron: there was not a trace of chromium.

Aragonite.

From Leadhills. *Strontianite* has been said to occur at Leadhills. Walker mentions this as a locality. The substance analysed was purchased in Jameson Torry's collection; and was named "Strontianite, Leadhills."

It could not be distinguished from green strontianite even under the lens: perhaps the radiating crystals were somewhat more glassy in lustre, and slightly more transparent.

I obtained:—

Carbonate of lime	96·430
Carbonate of strontia	1·730
Potash	·593
Soda	1·095
Water	·345
	100·193

This is a most singular result. The amount of carbonic acid obtained was sufficient merely to saturate the lime and strontia; still it is altogether inconceivable that the alkalies existed free.

Pale-green aragonite in small brushes of crystals, has recently been got at Leadhills; but this has no resemblance to strontianite.

Reddle.

This was found in imbedded nodules, in sandstone in Newton Quarry, near Elgin. It was soft and clay-like when damp; powdery when dry; colour deep and bright-red.

It yielded:—

Silica	55·746
Alumina	17·253
Ferric Oxide	8·263
Ferrous Oxide	1·655
Manganous Oxide	·278
Lime	·567
Magnesia	2·481
Potash	5·590
Soda	1·400
Water	6·550
	99·783

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Lydian Stone.

Occurs in the volcanic "necks" to the east of Kinkell, Fife; partly as volcanic bombs, consisting of perfectly formed Lydian stone: partly coating imbedded masses of altered shale, from which it had evidently been formed.

The shale in the centre of these masses, which are sometimes a foot or two in diameter, is much split up in the lines of its cleavage and cross-cleavage. The cleavages disappear when it passes into the vitreous Lydian stone, with conchoidal fracture.

The bombs are smaller, being rarely over half a foot in size. They are dense, conchoidal in the fracture, deep blue in colour; forming an excellent touchstone. The specific gravity is 2·598.

Silica	61·200
Alumina	17·536
Ferric Oxide	3·163
Ferrous Oxide	5·446
Manganous Oxide	·900
Lime	3·136
Magnesia	2·700
Water	5·889
	99·97

It loses 1·011 per cent. of water at 212°.

Hornstone.

This somewhat chalcedonic variety occurs in the clinkstone quarry on the north-east side of Blackford Hill, Edinburghshire.

The colour is brown; the mineral is translucent, but dull in lustre. It sometimes has a quartzy centre. Its specific gravity is 2·598.

It yielded—

Silica	89·692
Alumina	·974
Ferrous Oxide	1·373
Manganous Oxide	tr.
Lime	2·283
Potash	·540
Soda	2·271
Water	2·773
	99·906

Loses ·624 per cent. of the water, at 212°.

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Chert.

This occurs in veins of two inches in thickness, cutting the veinstone of the Fee Donald mine at Strontian, in Argyllshire. Its colour is pale emerald green; its structure is minutely granular; it has sometimes a colourless massive-granular centre; sometimes a quartzy centre. It contains imbedded cubes of *galena*.

It yielded—

Silica	89·692
Alumina	·769
Ferrous Oxide	1·671
Manganous Oxide	·076
Lime	2·843
Potash	·440
Soda	2·180
Water	2·005
	99·676

Loses ·22 per cent. of the water, at 212°.

Lignite.

Was taken from a bed which was under the "Organ," at the Giant's Causeway. This bed was overlaid by a bed of *plynthite*, which sometimes contained nests of augitic-glass.

It was underlaid by the "shale," an analysis of which follows.

The *lignite* showed the structure of dicotyledonous wood. In parts it was dull-brown and woody,—this had a specific gravity of 1·36. Other parts were dense black, and like cherry coal; both were analysed.

	Lignite.	Cherry Coal.
Gas	42·41	38·02
Volatile at 240°	4·44	
Carbon, residual	40·05	51·16
Water	7·18	7·72
Ash	5·92	3·10

The *shale* was of a black colour; it gave off no *inflammable* gas; and left a brown ash.

Gas	14·82
Carbon	4·23
Water	10·06
Ash	70·89

Ozokerite.

This name has been vaguely applied to substances which have not been analysed.

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The substance to which I apply it has been found, for many years, at Binny quarry, in Linlithgowshire. I have got lumps of it of half the size of a man's head. These have a rudely-foliated structure; a clove-brown colour, yellowish in thin portions; and they show an unmistakable fluorescence. It is brittle, easily cut, and very soft. It has a greasy to a waxy lustre, and a greenish reflection. Specific gravity ·961. 30·4 grains were analysed—

Naphtha, which has an odour of elastic bitumen, volatile at 205°	·691
Gas	96·974
"Free" Carbon	2·039
Ash	·372
	100·031

The ash was in thin brown shreds, somewhat like withered leaves.

The miners melt this substance up with tallow, and mould it into candles; these are nearly black in colour, and, from choking of the wick, burn very badly: there is also much carbon deposited from the flame.

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II.—*On some Ill-determined Minerals.*

By Professor Heddle.

Read December 23rd, 1880.

THE following substances have, for the most part, passed under the names here assigned to them; but they are themselves either ill-determined, or doubtful species: in some cases the name has been attached to certainly more than one specifically-distinct substance.

Plynthite.

From Quiraing in Skye. It occurs in layers of an inch or two in thickness, among the amygdaloids. It is usually of a deep-red colour and has a greasy lustre, but is sometimes earthy and dull.

It falls to pieces in water, and may, by this property, and its uniformly dense structure, be distinguished from the red *massive mesolite* which sometimes occurs along with it.

It yielded—

Silica	29·547
Alumina	19·027
Ferric Oxide	28·013
Ferrous Oxide	3·251
Manganous Oxide	·844
Lime	2·234
Water	17·391
	100·307

It loses 6·687 per cent of moisture, at 212°.

At the Storr in Skye it occurs in a *repeated series* of beds. It is evidently merely *bole*, and probably has resulted from *a bed of earth* which has been covered, and burnt by a trap stream.

Uigite.

Noticing in an old number of the Mineralogical Magazine a query as to *uigite*, it came to my recollection, that my description and analysis of this substance had possibly never appeared in a scientific journal, except

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in the Ed. N. Phil. Journ. II, iv., p. 162. I therefore give an extract from a notice of it, which appeared in the "Witness" newspaper of 12th March, 1856.

"Sixteen miles north of Portree, in Skye, lies the "farm town" of Uig. At about the fifteenth mile-stone, the road makes an abrupt turn to the east, before descending the hill; and just at this spot a small quarry has been opened for the purpose of obtaining road-metal. In this quarry I obtained indifferent specimens of *faröelite*, a single crystal of *analcime*, and a few pieces of a substance which, being unknown to me, I analysed, and which may be considered new. Should this be admitted, I would propose for it the name *uigite*. It occurs in small nests in the amygdaloid, which is here very vesicular, is not distinctly crystallized, being in radiated sheafy plates, somewhat resembling the structure of a plumose mica, but in general appearance is intermediate between *faröelite* and *gyrolite*; colour white, slightly yellowish; lustre tremulous and pearly; hardness, 5·5; brittle; specific gravity, 2·284; before the blow-pipe fuses readily and quietly, with strong re-action of soda, to a white opaque enamel, which is not frothy. On analysis it afforded on two occasions.

Silica	46·320	45·980
Alumina	21·348	21·928
Lime	16·361	16·150
Soda	4·698	4·685
Water	12·212	11·250
	100·939	99·993

These proportions give equivalents,—silica, 7; alumina, 3; lime, 4; soda, 1; water, 9. The mineral, therefore, consists of 1 equivalent of a silicate of lime and soda (where the lime is to the soda as 4 to 1), 1 equivalent of a sesquisilicate of alumina, and 9 of water. The calculated percentage proportions of which compound are,—silica, 46·09; alumina, 21·93; lime 15·97; soda, 4·46; water, 11·55; which percentages agree closely with the analytical results. No mineral has the above formula, which differs, however, from that of *faröelite* (mesole), merely in the insertion of the compound $2(Ca\,O, SiO_3)+H.\,O$. We have now to see whether it is not a compound mineral, *i. e.*, a combination of two minerals; (as its composition is capable of expression by a rational formula, the substance cannot be a *mixture*.) For this purpose, let us look for an instant at gyrolite, the new mineral lately discovered by Dr. Anderson, in Skye. That chemist gives $2\,(Ca\,O, Si\,O_3) + 3\,H\,O$, as the formula of gyrolite, which requires 15·40 per cent of water, but admits that the mineral readily loses water, and that none but specimens newly broken from the rock

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contain so large a quantity. While I myself am strongly inclined to think that even fresh specimens have an atom less of water, yet I am not at present prepared definitely to say so; but I am prepared to assert that the specimens of gyrolite ordinarily procurable, and such as are to be found in cabinets, have more probably the formula $2(Ca\ O, Si\ O_2) + H\ O$;—as I have obtained many such percentage proportions of water as the following ing:—6·417; 5·98; 6·83, &c.:—the last given formula requires 5·72. Gyrolite would thus seem to be a mineral which, like *Lomontite*, loses a certain quantity of water at once on the very exposure to the air; and, like *Lomontite*, this loss is accompanied with other changes—as of form, colour, lustre, &c.; for, when fresh, *gyrolite* is colourless, transparent, of a vitreous lustre, and tough; after a short exposure it becomes white, opaque, of a pearly lustre, and crumbles readily. Now, this latter formula of gyrolite is the very compound which we have to add to the formula of faröelite, to convert it into the formula of *uigite*,—as before shown. Three equivalents of *faröelite* united with one of *gyrolite*, will give a compound agreeing closely with the analysis of *uigite* and giving the same formula. I have already noticed that in appearance *uigite* stands intermediate between the above minerals. Under this consideration of the subject, therefore, *uigite* is made up of three equivalents of *faröelite*, and one of *gyrolite*; if we are not allowed to consider *gyrolite* as having ordinarily the above formula, then *uigite* must stand as a *simple* and not a *compound* mineral. I do not, however, dogmatically thrust it into the world as a new mineral; but, waiting for more information, would merely make a note that such a compound as I have described is to be found at Uig, in Skye."

In consequence of the modern reading of the composition of silica, the above formulæ have to be altered.

Ferrite.

This was sent to me by Mr. John Young, of Glasgow, as the *ferrite* of the late Wallace Young.

It was first given me, however, by the late Dr. Thomas Brown, of Lanfine, as "a new mineral." Dr. Brown's specimens,—which are identical in appearance, though hardly so well marked as Mr. Young's,—were from the neighbourhood of Kilpatrick.

Mr. John Young's specimens were from the Gleniffar Braes. The mineral occurs in crystals, imbedded in an altered dolerite. The crystals are deep red to chocolate brown in colour; they have two cleavages, which are both lustrous. They are easily broken, or rather split, along the cleavage faces; and they are so soft as to be bruised by the nail.

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Subjoined is its analysis, tabulated as obtained after heating in the water-bath, and also in its ordinary state.

	DRY.	ORDINARY.
Silica	13·544	13·025
Alumina	13·684	13·160
Ferric Oxide	55·600	53·473
Ferrous Oxide	4·691	4·511
Manganous Oxide	·154	·148
Lime	·780	·750
Magnesia	6·888	6·624
Water	4·744	8·394
	100·085	100·085

The mineral was found to lose 3·832 per cent. of water at 212°; and, as it was analysed by Wallace Young, *after having been dried at* 212°, the calculated percentages in the dry condition have been given in the first column, in order to compare them with the analysis of Mr. Young.

Mr. Young got in his analysis, 9·53 per cent. of *mixed quartz*;—deducting this, and adding 3·832 p.c. of water, to bring the constitution up to that of the mineral *in its ordinary state in nature*, we get the percentages in the second column, by calculation from the first.

Young's Analysis.

	DRY.	ORDINARY.
Silica *quartz*	9·53	
Silica	11·80	12·539
Ferric Oxide	68·93	73·272
Magnesia	5·26	5·591
Water	4·66	8·778
	100·18	100·18

At the first glance this appears a very different result from mine; but if it be supposed—which is far from impossible—that, in presence of the high colour of the precipitate obtained by ammonia, Mr. Young did not suspect alumina, and that he did not separately estimate the *ferrous* oxide—which at the date of his analysis was hardly ever done—but weighed and estimated the whole ammonia-precipitate as *ferric oxide*, the two analyses will be found to be really close.

My own analysis *tabulated in such a form*, is given as under 1; Mr. Young's as 2.

	1	2
Silica	13·025	12·539
Ammonia precipitate	71·793	73·272
Lime	·750	
Magnesia	6·624	5·591
Water	8·394	8·778
	100·085	100·18

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There can thus be no question that *the same substance* was analysed; and that the mineral is an alteration-product of either *augite* or *olivine;* indeed Mr. Young has sent me unaltered specimens of rock, containing imbedded and unchanged crystals of both of these minerals. Ferrite seems therefore to have a doubtful claim to rank as a mineral, or to be, at most, a pseudomorph.

Craigtonite.

Stains, dendrites, and thin filmy coatings on rocks, are very frequently pronounced to be "manganese" or manganesian; if these have a brown or even a blue colour.

I have qualitatively ascertained that this they sometimes, are,—to the extent at least of *containing* manganese; especially such as are seen in rifts of Old Red Sandstone. Only once however have I got a sufficiency to make anything approaching to a quantitative analysis. This single instance was a thin coating which adheres to red granite in the upper quarry of Craigton, Hill of Fare, Aberdeenshire. Its colour is blue-black; here and there it has a lustre like graphite; it cuts with the knife.

There being too small an amount to admit of its being picked it was dissolved off the granite by very weak hydrochloric acid. The acid seemed hardly to affect the *lepidomelane* present, and the granite seemed altogether unaffected. In addition to the lepidomelane, the granite contains only *orthoclase* and *quartz*.

The analysis of the solution gave—

Alumina	32·203
Ferric Oxide	38·305
Manganous Oxide	7·458
Magnesia..	16·610
Potash	4·745
Soda	·678
Silica	tr.
	99·999

As chlorine was evolved during the solution, the manganese must have been partly at least in the state Mn_3O_4.

I make no attempt to reduce this composition to any formula; and have given it a name merely as a nucleus to other analyses of the same or similar substances.

Ellonite.

This is an *ad-interim* name given to a pale dull yellow, somewhat unctuous powder, which I got out of small nests, occurring rarely in perfectly fresh recently blasted gneiss.

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It was from a quarry about half a mile west of the railway station at Ellon, in Aberdeenshire. The associated minerals, which were perfectly unaltered, were *orthoclase* and *lepidomelane* (?)

I obtained—

Silica	63·000
Alumina	3·051
Ferric Oxide	1·674
Ferrous Oxide	1·457
Manganous Oxide	·692
Lime	1·291
Magnesia	15·615
Potash	·630
Soda	·794
Water	11·700
	99·904

Loses 6·365 per cent of the water, at 212°.

There can be little doubt that there is free silica here;—though the powder was sifted through fine linen, to ensure uniformity. I can offer no opinion as to what the unmixed substance is. Possibly it may be of the nature of *cimolite* or *sepiolite*.

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A Peculiar Copper Ore from Coombing Copper Mine, Carcoar, New South Wales.

By A. Liversidge, Ass. R. Sch. Mines, Professor of Geology and Mineralogy in the University of Sydney.

Read September 2nd, 1881.

A dark-grey, almost black, copper bearing mineral, somewhat resembling Redruthite in general appearance, but of a duller lustre and considerably harder; the hardness being between 5 and 6. In parts a bronze tint and lustre is apparent. The specimen exhibits neither crystals nor crystalline structure, it breaks with a well marked conchoidal fracture. Lustre somewhat resinous; streak shining.

Heated in a glass tube it gives off water, having a strongly marked acid reaction, from the sulphurous acid which is evolved. Before the blowpipe it does not fuse, colours the flame green, and acquires a dull black colour. Treated with strong boiling nitric acid it is rapidly acted upon, a bronze coloured residue being left, the residue when examined under the microscope presents a honey-combed appearance; the walls of the irregular cellular cavities are pale-brown and translucent and apparently composed of quartz; when the powdered mineral is boiled with nitric acid, a white residue of silica is left. Concentrated hydrochloric acid also dissolves out the copper, etc., but much more slowly.

The mineral is intimately associated with quartz, both ordinary white vein quartz and a translucent variety of greyish tint; this grey tint seems to be due to diffused very finely divided copper subsulphide.

The specific gravity of a portion quite free from visible quartz was found to be 3·12 at 18°C.

The following analysis was made upon a portion which appeared to be perfectly homogeneous even under a one-inch objective, yet this yielded over 43 % of silica.

Analysis.

Water, combined	2·354
Silica	43·420
Copper subsulphide (Cu_2S)	45·196
Iron Sulphide (FeS)	4·931
,, Sesquioxide	3·479
Undetermined and loss	·620
	100·000

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The combined water was determined directly by collecting and weighing it in a chloride of calcium tube, a layer of lead oxide being placed in the front part of the combustion tube to arrest any sulphur or sulphur oxides.

The amount of silica soluble in a boiling solution of sodium carbonate was also determined in two other specimens.

	I.	II.
Soluble silica	14·69	19·99
Insoluble	22·13	14·81
Total silica ..	36·82	34·80

The mineral therefore appears to be merely an intimate mixture of amorphous and crystalline quartz, with copper subsulphide and more or less iron combined with oxygen and sulphur.

III.—*On the occurrence of Linarite in Slag.*

By Patrick Dudgeon, Esq., Cargen, Dumfries.

Read September 2nd, 1881.

With reference to Mr. Terrill's notice of "Crystallized products found in smelting operations" (Min. Mag. No. 19, p. 133) it may be interesting to notice the occurrence of Linarite in the cavities of the slag from an ancient lead smelting place in this neighbourhood. There are several ancient smelting places in the district where both lead and iron have been smelted, from the remnant of pottery found at the places they are evidently of Roman origin; there are no written records whatever of smelting operations having been carried on in this district, and it is difficult to conjecture where the ores smelted came from, the nearest known lead viens being 40 miles distant, and although insignificant veins of hematite occur in the neighbourhood, it seems impossible that sufficient quantities of the ore could have been collected in the vicinity to account for the very considerable heaps of iron slag found in two or three places. On examining one of the lead smelting places, on the farm of Martingarth, parish of Troqueer, I broke up some of the slag, and in some of the cavities found well-formed crystals of Linarite: the crystals are small, not above from 2 to 3 mm. in length, but perfectly defined and unmistakeable it is most probable that the mineral has gradually crystallized in its cavities during the long period the slag has been exposed to the atmosphere, and not that it was formed during the process of smelting. I found no other crystallized minerals in the cavities.

The process of smelting appears to have been very imperfectly carried on, many pieces of unreduced galena and globules of lead being found in the slag.

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IV.—*On some Artificial Forms of Silica, illustrative of the structure of Agates, Chalcedonies, &c.*

By J. I'Anson, F.G.S., and E. A. Pankhurst.

(*Read September 2nd*, 1881).

IT is a common chemical fact, that when a solution containing an alkaline silicate is acted upon by any reagent capable of separating the silica from the base, the silica is in the majority of cases thrown down in a solid form. The fact of this reaction is all that, as a rule, the chemist would look at: but in addition to the mere chemical fact of the precipitation of the silica, another most important element from the mineralogist's point of view is that of the *form* in which this precipitate of solid matter appears. This form naturally varies with the various conditions of the experiment, and it is by the study of these varying forms that the authors have sought to elucidate, experimentally, the wondrous and beautiful varieties of structure which are so familiar to us in the endless forms of silica occurring in nature.

The infinite variety in the great group of banded agates falls readily into two types. The *first* in which the solidification appears to have taken place in successive layers from within *outwards*; and the *second*, in which the impression is conveyed that the order of growth has been from without *inwards*.

In both cases, beyond the successive bandings there is very frequently observed a crystalline mass of silica, which does not present the banded structure.

In the first class this crystalline mass is to the *outside* of the banded part; in the second, it is towards the *inside*, as though there had been a central cavity within the bands which had become filled with crystalline unbanded silica.

Assuming, for the convenience of nomenclature, that these two types are the results of the two methods of growth indicated—a view we hope to justify in the course of this paper—we may name these the *exogenous* and *endogenous* types respectively.

With the exogenous type of agate are grouped such stalactitic forms of silica as show in transverse section a series of concentric rings or bands: and a careful examination of cut stones of this class

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will shew the extreme frequency of the occurrence of these stalactitic forms in agate structure, more especially when such structure is intimately examined in microscopic sections. The last layers of a portion shewing exogenous growth frequently become the first of an adjoining portion, whose growth structure falls under the endogenous type.

The unbanded and mossy types, occurring in such stones as jaspers and moss-agates, form a separate group, of which we shall have something to say further on.

Let us now first take the *exogenous* or stalactitic type, and seek by experiment to elucidate its genesis and structure.

We may get stalactitic forms of silica by taking a solution of silicate of potash or soda, and dropping into it, or allowing to run down the sides of the containing vessel, any of the strong acids; but in order to get the best results and to produce the beautiful branching coral-like forms, our mode of procedure is as follows.

A strong solution of silicate is taken containing a certain amount of alkaline carbonate, and a strong acid (sulphuric seems to give the best results) is introduced by means of a pipette to the bottom of the vessel in which the solution is contained.

Bubbles of carbonic acid gas immediately arise, carrying with them a certain amount of the stronger acid. Round the stream of ascending bubbles, silica is deposited by the decomposition of the alkaline silicate, and in a very few minutes a tube is formed reaching from the bottom to the surface of the solution.

This tube is at first very thin, and through its walls the ascending acid continues to act upon the surrounding silicate, the walls of the tube in consequence constantly growing in thickness by the deposition of additional silica on its outer surface. As long as the flow of acid is kept up, so long does the tube grow in diameter by the deposit of successive layers, and the result is a hollow stalactite ringed in cross section.*

The carbonic acid evolved from the carbonate in the solution is essential to the successful commencement of the tube, but when this is once formed, the sulphuric or other acid can be itself forced through it, and by the application of pressure to the surface of the fluid in the pipette, the action can be kept up for a long time, and stalactites of $\frac{3}{4}$ inch in diameter can be formed with little difficulty. The same result can be produced by passing an acid gas, or even air highly

* Plate 1, Fig. 1. shews a group of such stalactitic growths of silica. At A and B these have come in contact with the sides of the containing vessel, and have thus been made, as it were, in section, shewing their hollow nature.

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charged with an acid, through the alkaline silicate solution, and it will easily be seen that analogous effects can be produced by the action of any other reagents capable of separating the silica, such as acid salts of various metals. In fact the process can be varied in a hundred different ways. In natural siliceous stones where stalactitic forms enter into the structure, we constantly observe a central core, frequently of iron or other oxide, which appears to represent the original tube which has subsequently been filled up, whilst sometimes the cavity remains more or less completely as such. These stalactites of course do not grow up by any means in constantly straight regular forms, but assume irregular and branched ones, more like those of coral than anything else, according to the direction in which the bubbles of gas or the acid escapes from the end, or from points of least resistance in the sides, of the tube. Glauber's "Iron tree" is one form of this stalactitic growth.

The specific gravity of the fluid in which the stalactites are made, as compared with those of the reagent employed and of the precipitated silica, has of course much to do with the form assumed. Where these are equal, the tubes may take indifferently any direction with regard to gravity—and this is precisely what we find in nature, where it sometimes appears as if gravity had not had much to do with the directions assumed.

We consider then that the stalactitic productions thus made are the analogues of all the group of banded stalactitic growths which enter so largely into the constitution of many siliceous stones, where the growth appears to have proceeded from a central cavity, now frequently only a core, by reason of subsequent filling in.

If the action is carried so far that the surrounding fluid becomes saturated with acid reagent, the whole of this surrounding fluid gelatinizes by the precipitation of amorphous gelatinous silica, and if we suppose a case in which such stalactitic forms have been produced in nature in an enclosed rock cavity containing an alkaline silicate solution, by the infiltration of an acid solution, a like result would occur. In point of fact, as we have already stated, such natural forms constantly occur with a surrounding mass of crystallized unbanded silica, and this we are led by many observations to regard as the analogue in nature of the gelatinous silica resulting from the saturation of the fluid in which the stalactites have been formed. Whether in nature this crystalline silica has been originally deposited in a gelatinous form, and subsequently crystallised, is a little out of the scope of this paper: but analogy leads us to regard this as most probable.

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II. We come now to the question of the formation of banded agates of what we have called the *endogenous* type; which are in reality, so to speak, the converse of the type of structure which we have just been considering.

Assuming hypothetically a rock cavity containing a solution of alkaline silicate, and the rock in which this cavity is situated permeated with an acid solution or gas, we should naturally expect to find a layer of silica deposited on the walls of such a cavity, and as the action continued more and more silica would be deposited; and if the solution were *enclosed* in the rock cavity, the central portion would, when the action had continued to a certain point, set in an amorphous mass.

This action is very completely parallelled in some of the preparations which we have made, and in some of these we have found that a central vacant space was left, owing to there not being enough silica in the solution to fill the whole cavity when precipitated in the gelatinous form. This is precisely what occurs in many natural agates, where we find a deposit of crystalline unbanded silica within the banded portion, with a vacant space in the centre of all.

We have, so far, dealt only with the production of these various forms in more or less pure silica: but by the use of acid solutions containing various metallic and earthy salts, we can imitate, to a great extent, the colouring of natural stones. More especially is this the case in the next group with which we have to deal.

Jaspers, Moss-agates, &c. The varieties of structure of the class of stones roughly grouped as above, are exceedingly interesting and beautiful. The way in which the various colouring matters are arranged, suggests at once the idea of *chemical precipitates*, and although, perhaps, the different types of structure are not so strongly marked as in those groups with which we have already dealt, yet there is much of interest in their elucidation.

Perhaps the most prevalent colouring matters in this class of stone are the red and yellow ferric and the green ferrous oxides. Both these classes may be readily imitated by introducing into alkaline silicates various ferric and ferrous salts. If an acid solution of a ferric salt—for instance ferric chloride—be so introduced, we find, first, a more or less flocculent precipitate coloured red or yellowish; and subsequently, as the action goes on, around this grows a filmy white deposit of silica, which frequently falls into banded forms, precisely analogous to constantly recurring markings in jaspers and allied stones. With ferrous salts, again, the green mossy markings of the moss-agate and the darker colour of the onyx can be perfectly produced.

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Many interesting forms can be obtained by allowing stalactitic forms to come in contact, as they grow, with the sides of the containing vessel, by which means they may be made, as it were, in section, and the progress of their growth readily and conveniently watched. By combinations of these methods, a vessel may be entirely filled up with different forms of structure and colouring, presenting a very close resemblance to the natural products whose genesis it is sought to illustrate.*

It would be impossible within the compass of a paper of any reasonable length to go into all the variety of solutions and reagents with which we have worked, or to give all the special coincidences with natural form and structure which we have observed; but the following brief notes of some such special points may be of interest.

Horizontal banding is frequently met with in natural agates, and we have found it very completely reproduced in many of our preparations.

Some alkaline silicate was poured into a dilute solution of silicate of soda, which had been previously acidulated with dilute hydrochloric acid. A jelly was at once formed, enclosing in a species of cavity a portion of the alkaline solution. Into this the hydrochloric acid, together with the chloride of sodium resulting from the decomposition of the silicate, exuded from the gelatinous mass, and a series of horizontal bands extending across the cavity gradually formed.†

A solution of commercial alkaline silicate, particularly silicate of soda, is capable of dissolving considerable quantities both of pure gelatinous silica, and also of various silicates, such as those formed by precipitation with sulphates of copper and iron, as well as those of the alkaline earths.

In watching the growth of these stalactitic accretions in section on the sides of the containing vessel, the production of the bands has been observed to vary with different conditions of—1st, temperature, 2nd, acidity of precipitating solutions, 3rd, pressure.

If a solution of ferric sulphate, ferric chloride, or cupric sulphate, be poured into an alkaline silicate, coloured precipitates result, which, when washed, we have dissolved in alkaline silicates, producing the

* Plate II shews two examples of this. In both preparations the growth has commenced by stalactitic forms coming in contact with the sides of the containing vessel, and by continuing the action these have developed a series of successive bands external to the original tubes. The space beyond these bands consists of almost structureless silica due to the ultimate saturation of the alkaline silicate with the acid reagent.

† Plate III, fig. 1.

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purplish red and green solutions exhibited, by the use of which in our preparations we have found the various colours of natural stones very closely imitated.

Hair-like Enclosures in Silica.—To produce the specimens figured in Plate III, fig. 2, the following process was adopted. A solution of silicate of soda, containing carbonate of soda, was taken; at the bottom of the vessel small fragments of acid salts, such as ferrous and ferric sulphates, were placed. The action of these on the carbonate in the solution gave rise to very minute bubbles. These ascending through the solution were followed by others, till a tube was formed reaching often to the top of the alkaline liquid. In the reaction between the iron salt and the solution, the tube became filled with a ferruginous liquid, and thereby coloured red, brown, or black, according to the substances employed.

So-called "Orifices of Inlet."—When the continuity of the bands is interrupted by the escape from within the cavity which they surround of the contained acid solution or gas, an appearance results closely resembling the so-called "Orifices of Inlet" in natural agates. The bands are bent outwards and thinned away at their interrupted ends, and at times the space between them is filled with a tubular stalactitic form, as shewn in Plate 1, fig. 2. Our observations and experiments enable us fully to confirm the view of those who hold that these so-called "Orifices of Inlet" are in reality more or less complete efforts to form outlets.

The precipitated silica in these preparations, being deposited at no great pressure or temperature, of course falls far short of a perfect reproduction of the natural stone in point of hardness and stability. Exposed to the air they, for the most part, dry up and crumble away, although we have produced some forms which approximate closely to common opal in appearance, though of lower specific gravity, and these remain with little or no alteration after once being dried. It is only in form and structure that we can as yet claim to produce any imitation of nature's products: but it is conceivable that under suitable conditions of heat and pressure closer imitations might be made.

How far in nature the assumption of a crystalline structure may have taken place subsequently to the original solidification, is a question upon which, so far, we can only speculate; but we think it is probable that this may, to a great extent, have been the case. We do not touch upon this point in other than a tentative sense, in the hopes of eliciting from others any evidence which they may be able to offer on the point.

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In conclusion, we have to acknowledge our indebtedness to Messrs. Gossage, of Widnes, for very kindly and generously placing at our disposal the material necessary for these experiments.

Mr. Wm. Lant Carpenter (B.A.,B.Sc.,F.C.S.) as a visitor, but as a late manufacturer of silicate of soda, begged to congratulate the authors upon their very admirable paper, and to offer two remarks thereon. The authors had been unable to obtain specimens of precipitated silica possessing any degree of hardness, most of them drying up and crumbling. About 15 years ago he had had occasion to prepare, on a large scale, great quantities of precipitated hydrated silica, by decomposing solutions of sodium silicate (sp. gr. 1·250) at 230° Fah. with excess of hydrochloric acid. In the tank, underneath the gelatinous silica, when cleared out after 4 or 5 operations, was a layer of *extremely hard* silica, which required a very sharp steel pointed pick for its extraction. This had a fracture very like that of flint, and he had kept it till the present time without any diminution of hardness; it would not quite scratch glass, but was intensely hard. He had never published the observation.

The other point related to the concentric veins seen in the natural agate, and in those now shown. Just as albumen when coagulating in a fluid attracted to itself minute suspended particles (hence its use in clarifying sugar solutions), so colloid silica at the moment of its liberation in the nascent state, as it were, attracted to itself minute suspended particles, and it was in this way, he conceived, that these concentric veins or markings were formed from the mechanical impurities present in the solution

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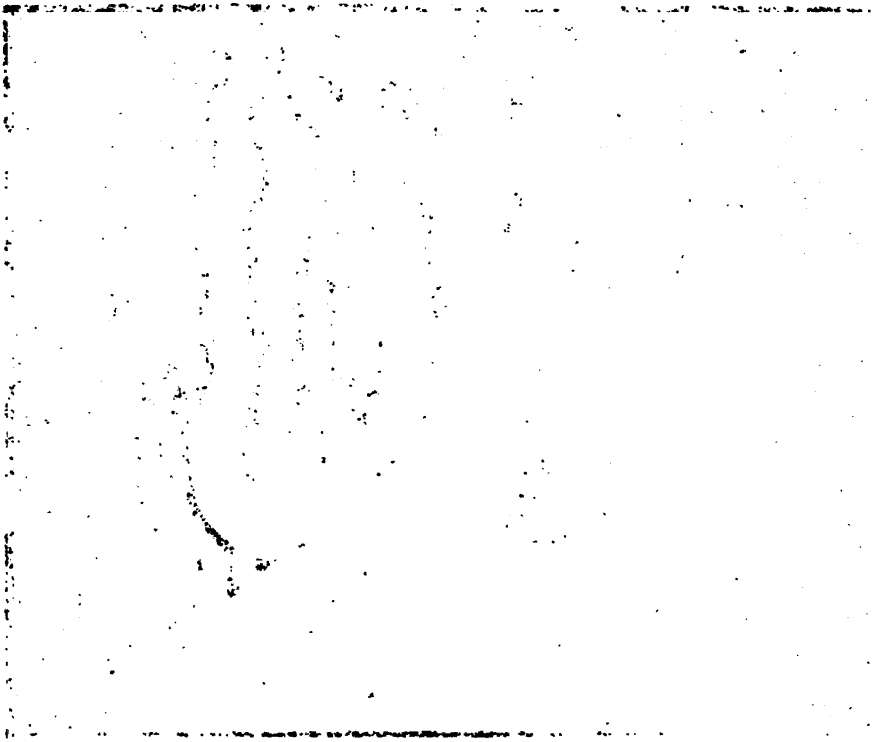

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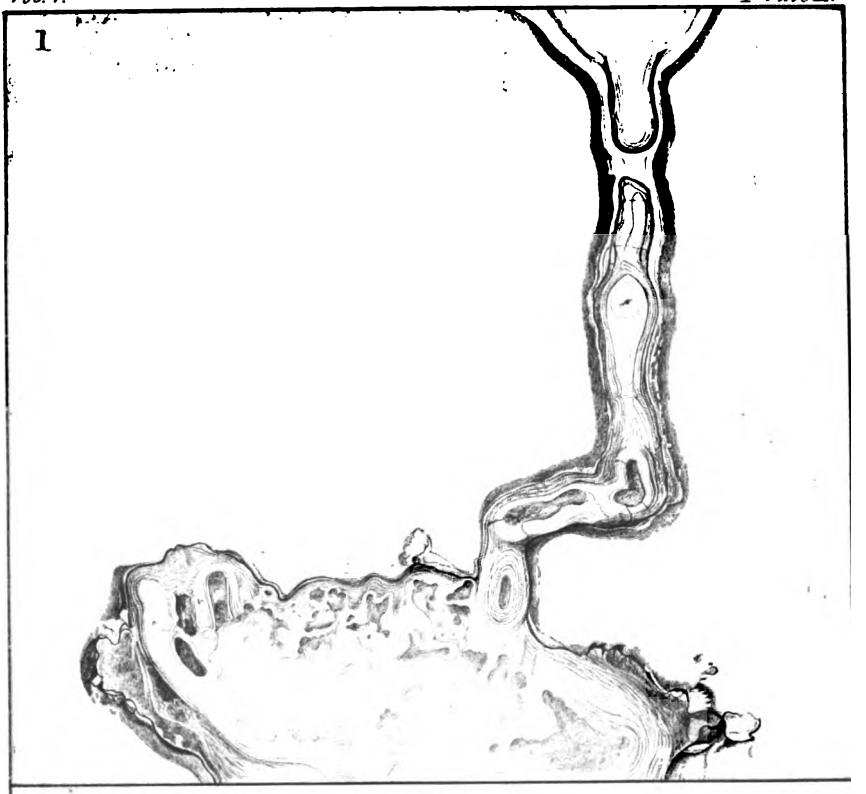

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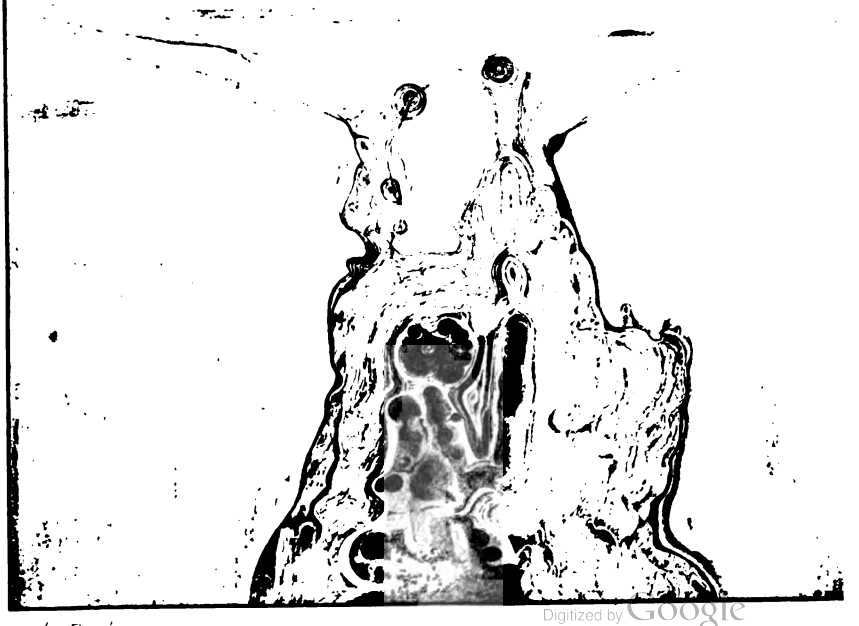

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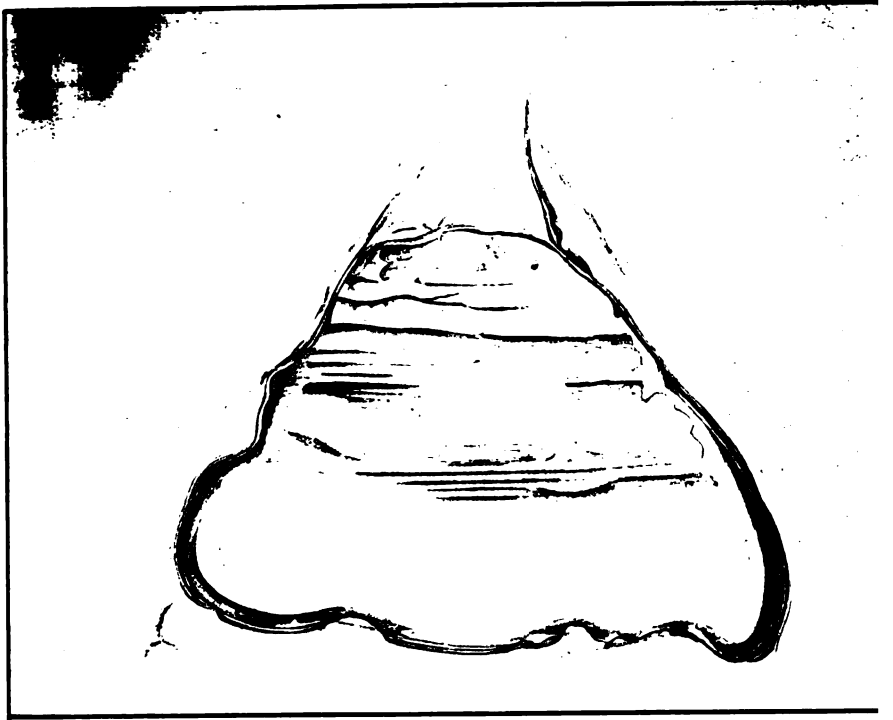

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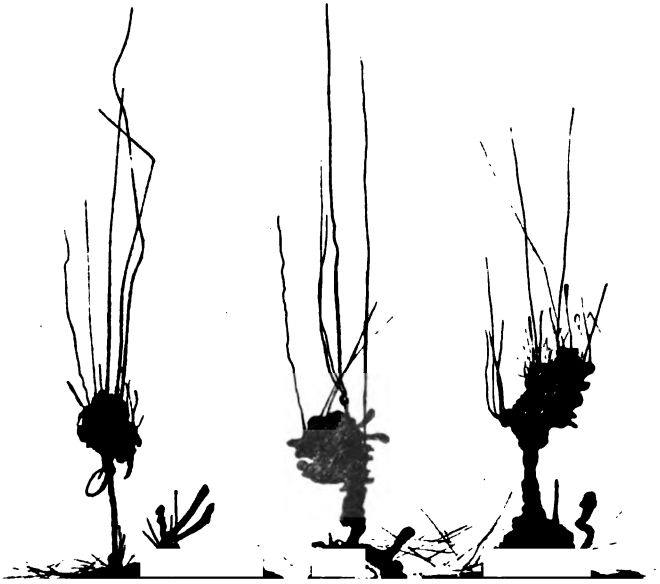

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DESCRIPTION

OF THE

GEOLOGICAL MAP OF SUTHERLAND.

By Professor Heddle.

IT was with considerable reluctance that I felt myself compelled to discard the system of coloration adopted in the Geological Survey Maps; and this I did only after the strongly expressed opinion of several geologists.

It was not that I have any very intense desire to colour rocks after their natural tints, but I have an aversion to adopting a colour suite which departs markedly therefrom; or one which is in discordance instead of harmony therewith. One friend, a man of great scientific discretion, and himself an artist, writes me that when he looks at a recently published geological Map of Scotland, with its grey Torridon and its red Laurentian, he does not know whether he is standing on his head or his heels. I must say that I share the feeling intended to be therein expressed; and hold that, if there is to be an absolute departure from the tone presented by the rocks themselves, we, at least, should not have the incongruity of a bed of a sombre or dark hue, reposing upon one of a markedly lighter tint.

The colours, then, which have been adopted, if they differ from such as were formerly in use, have been selected upon the foregoing principles; namely, some resemblance to nature, and the keeping the graver tints for the more profound rocks.

There is what may be considered a departure from this, in the case of the lively tint given to the so-called "igneous rock." As this rock much resembles in many ways the Hebridian gneiss,—being only of a lighter tint,—a green was also chosen for it. While it may be urged that there is here too marked a distinction between it and the quartzite series to which it belongs, it has to be stated that a pronounced and brilliant colour was chosen, (to, perhaps, the detriment of the map as a whole,) in order that attention might be drawn in a forcible manner to *the* rock which the writer maintains will prove to be the key to the reading of the much-contested geology of the district.

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In proceeding to direct attention to some of the features of the map, and to the facts which it evidences, the author has in the outset to state, that for all the lines laid down on the eastern side of the county, he is indebted to Dr. Joass, and to Professor Judd. To the first for much information imparted both by word of mouth and by letter;—to the latter for what is in fact almost a pantographed transcript of his published map of this eastern district.

The Old Red Conglomerate which caps the summit of Ben Armine, was inserted upon the authority of Mr. Crawford, of Tongue.

The author is responsible for almost every line of the rest of the map, (some few errors being corrected). It may be that certain of the lines are much the same as those which have appeared in former maps, especially in that of Cunningham;—if so, they have been verified.

The following are the points or localities which he has not verified, or has inserted chiefly on information derived from others.

The whole line of junction of the Torridon of the Rhu Storr with the Hebridian gneiss, is taken from Macculloch. The occurrence and the exact site of the upper limestone at Fier Loch Karstich, and at Loch Strathnashvish. The former he could not see from a height at a distance of a mile; the greenery of the latter he did see at the spot laid down, from the slopes of Ben Leod.

The position of the dolomite (and whether it was touched by the igneous rock) at the back of Craig Dionard.

The lines of junction of the upper quartzite with the "igneous rock" and with the upper gneiss, were not *walked along* between Loch More and the slopes of Ben Leod; though they were *seen* in their higher rolls from the summit of that hill;—and *portions* of the line of junction of the upper gneiss were not walked along at the back of Ben Uidh, and eastern Ben More; as also at the hill Arkle.

Every other line of junction was either walked along, or was so immediately under the eye of the writer, that he is, in all localities of importance at least, prepared to submit them as being nearly absolutely accurate.

As the amount of confidence which is to be placed in a geological map must in a great degree depend upon the extent of ground walked over,—and, as there is no better way in which to submit this than by enumerating the hills climbed, there is subjoined a list of the hills with their heights, which the writer ascended between Loch Torridon and the north shore. The whole of that district he explored with nearly equal care, before he considered that a sufficiency of data had been collected to entitle him to assume an assurance of expression equivalent to that which has been assumed by others.

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Torridon, Dundonnel, and Kinlochewe Districts.

	feet.
Leagach, south top	3358
Ben Eay,—whole ridge	3220
Fioun Bheinn	3060
Benin a Mhuinidh	2267
Slioch	3260
Sgurr an Tuill Bhan	3058
A'Mhaighdean	2995
Benin Tharsiunn	2965
Mullach Coire Mhic Fhearchair ...	3300
Sgurr Dubh	2950
Meallan Laoch	1950
Sail Liath...	2982
Corray Buidh	3041
Scurr Fiona	3474
Glass Meall Liath	3082
Bidein, a Ghlas Thuil	3493
Glas Meall Mhor	3176
Sal Mhor	2538
Beinn Dearg	3547
Beinn Aonachlair	2915
	60621

Coigach and Assynt District.

	feet.
Beinn Eilideach	1755
Ben More, Coignach; east top ...	2285
Coul Beg	2525
Stack Polly	2009
Coul More	2786
Cromalt Hill	1265
Cnoc na Glas Choille	1008
Cnoc na Meallain	1225
Cnoc na Stroine...	1306
Cnoc Ledbeg	1200
Cnoc an Leathaid Bhuidhe	1205
Braebag	2670
Ben a Bhrachaidh	2334
Braebag Tarsuinn	2328
Beinn nan Cnaimsheag	1740
Canisp	2779
Suilven	2399
Sgonnan Beg	1240
Meall a Bhuridh...	1380
Carn nan Conbhairean	3190
Ben More...	3273
Coineveall	3234
Na Tuadhain	2824
Ben Uarran	2644
Mullach an Leathard Riabbaich ...	2410
Beinn Uidh	2384
Cnoc an Drian	1560
Glas Bheinn	2541
Cnoc na Craige	1745
Quinaig	2653
Stack of Glen Coul	1740
Rhi Chnoc	1730
Beinn Leod	2597
Meallan a Chuail	2461
	72445

Reay Forest, and the North.

	feet.
Ben Hee	2864
Carn an Tionail	2484
Carn Dearg	2613
Meallan Liath Coire Mhic Dhughaill	2625
Meallan a Loin	2483
Meall Garbh	2471
Benin Laoghal	2504
Benin Heil	1780
Meall Leathad na Cnaoibhe ...	1018
Beinn Bhreac	1020
Cnoc an Fhreicadain	1009
Ben Hope...	3040
Ben Strome	1543
Ben Stack	2364
Handa Island	406
Foinaven	2996
Cnoc Poll a Mhurain	503
Cnoc a Gheodha Ruadh	598
Sithean na h'Iolaire	758
Diman Mor	523
Clo Mor	630
Meall Sgribhinn	1316
Crann Stacach	2630
Beinn Spionnaidh	2537
Cnoc ard an Tionail	603
Creag Mheirgeach	746
	43954
	60621
	72445
	177020

The grounds upon which I base the sequence of rocks, which I believe to be the true one in this county, will be submitted elsewhere,* in describing *eighteen sections*, drawn between Kinlochewe and Loch Glen Coul. I must content myself at present with a few brief remarks upon the rock, which, from its having been generally designed as such, I have in the map termed the "igneous rock," of the quartzite.

This rock I find to occupy an unvarying position.

When it appears as a single bed, that position is immediately over the Dolomite. When more beds than this one appear, they are as invariably to be found intercalated in the upper quartzite.

This rock has given rise to an almost endless amount of controversy; an amount which the writer is satisfied would have been minimised, had only the twentieth part of the time been devoted to observation

* Transactions of the Royal Society of Edinburgh.

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of it in the field, that has been frittered away in discussing it, upon all too narrow grounds;—indeed in many cases from an examination of it, at but a single locality.

According to some of the writers and disputants who have treated of this rock, it has broken through at various horizons, the junction rocks, along the whole line of strike from Whitten Head to Loch Maree; (indeed, according to one, as far south as Totaig on Loch Ailsh).

According to others, it only *appears* to have broken through these rocks; having in reality been so positioned through faulting. While, according to others, it is held to be conformably bedded with the other members of the higher formation.

We also find that petrologically it is, according to

Cunningham ...	Upper Gneiss.
Nichol ...	Intrusive.
Murchison	
Harkness...	
Hicks ...	
Geikie	Upper Gneiss, metamorphosed in situ, from the near presence of lime.
Hudleston ...	Old Gneiss, faulted up, and partly invaded by extravasated matter.
Bonney	Old Gneiss, faulted up, its upper portions crushed, especially when near lime; and sometimes granitoid from predominance of felspar.

Of the above writers, Cunningham, Geikie, and Bonney, recognise or admit conglomeritic or brecciated structure, in this rock; while Nicol, Murchison, and Hicks, do not recognise, or overlook this.

Again Cunningham, Geikie, and Bonney vouch for a laminated structure, and a rude bedding, as being "sometimes to be seen," or "apparent"; while Murchison and Hicks do not recognise this, and Nicol very seldom does.

Cunningham, Harkness, Ramsay, Geikie, and Murchison, hold that it does not "break up" the upward succession of the rocks; Nicol, Bonney, Hudleston, Hicks, and lately Callaway maintain that it does.

In presence of so great a turmoil of opinion as the above, is it any wonder that Mr. Hudleston, in a most successful endeavour to "act the part of an impartial historian," should write—"Dr. Hicks, like all previous authors, is not a little troubled by the "igneous rocks,"—or that he should admit that he himself was "in a fearful fog as regards the merits of the whole controversy,"—and that the summing up of his critical sketch should be the finding, and there "was room for further examination."

Sir Rhoderick Murchison writes:—"it in no way hinders the observer from developing a clear and conformable order of superposition." The present writer goes a great deal further than this, and maintains, that,

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while there are many sections where a clear order of superposition is developed without any material aid from this rock,—indeed, where it is not even present,—that still, in the more disturbed districts there is little hope of unravelling the *apparent* confusion which exists, without bringing in the aid which a thorough knowledge of the position or positions of this rock can afford.

Of the above authors, Cunningham, Nicol, Murchison, and Geikie, refer to the rock or rocks, as seen at several localities; the others at but few, or even at but one, and that one the locality where, perhaps of all others, it assumes the extreme of one of its appearances.

Had these authors walked along the strike of this rock—best at its lowest edge—picking up the dolomite along that strike, invariably in the same relative position, *one* if not all of the points at issue would have been rapidly resolved into a common stand-point of agreement.

As to the precise nature of the rock,—this has been pronounced upon by some of the more recent writers (after an amount of exploitation which their descriptions show to have had the proportions of a post-prandial saunter) with an amount of assurance which the present writer feels that even an extent of walking very inadequately vouched for by one hundred and seventy seven thousand feet of climbing, *does not entitle him to assume*. He would beg leave to refer to his paper before mentioned for his views; merely stating here that his opinion coincides with that of Cunningham and Geikie.

And he would submit the following facts, in controversion of the *two* views that it is the older gneiss,—and that it is an *eruptive* igneous rock.

First.—The invariability of its position throughout a stretch of over seventy miles; always *over* the dolomite, and if there be more beds than one *in* the upper quartzite; if there be only one bed, it underlies the upper quartzite, where present; the upper gneiss, where not present.

Second.—That along the whole line, at least from Loch Maree to Whitten Head, it at no spot shows a neck, or point of outflow.

Third.—That where it occurs in the upper quartzite, in five closely adjacent beds at Cama Loch, these beds never run into one another, or branch, tothe smallest extent.

Fourth.—That where it is seen in highly-faulted localities, as at the east end of Mullach an Leathaid Riabhaich and elsewhere, it is never seen entering the rents, itself; but occurs in its proper place, as a layer or bed in the dislodged fragments.

Each of the above facts would throw doubt upon this being an eruptive igneous rock; taken collectively their evidence to such an effect could hardly be more complete.

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There is, however, another fact connected with this rock, which has much significance. It is, that, apart from the constituents special to it, it contains *no* minerals. Imbedded crystals—druses—and veins, are alike unknown to it. Can a barreness of such a nature be shown to occur in an eruptive igneous rock of equal bulk, elsewhere?

This feature also serves to distingnish it from the lower gneiss, which many contains accessory minerals.

The sequence of rocks, which the writer holds to exist in Sutherland, is as follows :—

Hornblendic Gneiss	High dip to W.S.W. and S.W.
Conglomerates; small in grain, much attrited, no limestone fragments	Along west shore dipping at 5° to 7° to W., or W. by N. Ten miles inland, dipping 5° to 7° E. by S.
Quartzite; with intercalated large-crystalline porphyry, and rarely fine grained beds ...	Overlying *eastern* portion of the conglomerate only; with dip to S.E., 10° to 30°.
Yellow flaggy argillaceous beds	Conformable.
Fucoid beds	Do.
Dolomite; with occasionally yellow quartzite layers, and a band of "trap" ...	Do.
Fissile chloritic beds	Do.
"Igneous rock;" sometimes cut vertically by dykes of dark-green "trap" ...	Do.
Upper Quartzite; containing sometimes four intercalated beds of the "igneous rock;" and an albitic porphyry, which sometimes cuts it in thin dykes, and sometimes is intercalated. ...	Do.
Limestone; of from two to several beds, separated by beds of flinty quartz-rock ...	Do.
Beds of Quartz-rock, resembling "hornstone"	Do.
Gneiss of very varying features; sometimes plicated "chloritic;"—sometimes flaggy micaceous;—sometimes hornblendic, crystalline, ...	Do. but a few miles to the east, the dip in the north of the county, swings round to the north; while in the south, it swings round to the south.
Breccia; very angular, large in grain, with limestone fragments	Unconformable; dip in the north, 5° to 15°, N. by E.
Conglomerates, not smoothly attrited ...	Conformable.

It is about forty-five years since one of the most conscientious and hard working of Scottish geologists told us that, in Sutherland, one gneiss was overlaid by conglomerates unconformably; that, in turn, by quartz rock, also unconformably; that, by a sequence of limestone,—quartz-rock, —a second limestone,—with a second gneiss, all conformable with one another. The same geologist described the "igneous rock," as a mere variety of the second gneiss.

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The sequence now given, *is merely this old sequence*, stated in more detail. Chemistry has told us that the *first* limestone is Dolomite; and new traverses,—perhaps still more extended than those which the enthusiastic Cunningham was able to undertake,—rendered practicable through the open-handed hospitality *of a whole county*, at the behest of its noble proprietor,—enable the writer to state that the rock which Cunningham described as a mere variety of the upper gneiss, is to be regarded as such, and nothing else; if we are to be guided in our conclusions by such facts *as* its occurring among beds of rock which are conformable with that upper gneiss; *and as* its differing from the ordinary appearance of that gneiss to no whit a greater degree than do the beds of that rock itself which occur at the Whitten Head, and over the whole tract of ground which lies between Tongue and Farr.

The following errors have crept into the map.

At one or two points the colour of the upper gneiss has been swept too far westward; it has thus broken the continuity of the quartzite band; as between Foinaven and Arkle, and between Arkle and Loch More. At one or two points it has covered over ground intended to be left *uncoloured*, on account of its being concealed by swaddling and swarding.

The fault at Knockan, and the quartzite tip on Suilven, should be removed.

The fault at Loch Borrolan has to be removed southward, *a quarter of an inch*; so as come in the line, and under the influence of the marks of doubt;—it being a very-doubtful fault.

A mark of doubt has to be inserted at the *middle* of the Ben Uarran fault; as this probably dies out, about the glen between Coineveall and Ben Uarran.

The anticline is placed too far up the slope of Ben Uarran.

The fault which cuts the limestone of Smoo off from the quartzite, should not extend west, so as to intersect the faults which let-in the gusset of upper gneiss. These faults of necessity must intersect to the south; but where is not known. The fault running from head of Loch Glen Coul (if it exists), dies out about two miles up the glen; and does not intersect the faults which bring up the great wedge of "igneous rock."

There are some trifling errors in detail, but none which are vital.

Had the writer acted upon theory, even to what might be regarded as a legitimate extent, he would have connected the "igneous rock" of

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Sconnan, with that of east Ben More. He saw it at some intermediate spots, like stepping-stones, the whole way across; but he did not walk over the ground, at the stream side; and therefore the green band was not made continuous.

Agreeing as he does with Nicol (and lately Callaway) as regards the dolomite of Stronchrubie lying in a basin, he does not agree with either, as to the inferences to be drawn therefrom. A great semi-circular, anti-clinal-roll of the lower quartzite troughs the dolomite; which has thinned out before it plunges under the "igneous rock" of Ben Bhrachaid; but the *argillaceous beds* are there seen, dipping under the "igneous rock."

He also differs, altogether, from both of the above writers, as to the Cnoc-an-drian section; maintaining that the views of Murchison, Harkness, and Geikie as to it, are correct; though he cannot agree as to the *details* of the sections given by either Murchison, or by Harkness.

V.—*Note on Artificial crystals of "Specular Iron" formed in a Copper Works Slag.*

By W. TERRILL.

Read September 2nd, 1881.

SINCE my last communication on Artificial crystals (Min. Mag. No. 13), I have met with some very remarkable crystals formed in a Copper Works Slag which consisted mainly of Cuprous Oxide and Ferric Oxide with a little lime, a product from melting a charge of "copper precipitate."

The crystals are hexagonal plates, bounded on the edges by the faces of a rhombohedron which roughly measured gives an angle of R : R=86°. They are iron black in color, with a splendent metallic lustre, and contain 50% Ferric Oxide with 45% copper.

Examined under the microscope or even with a strong lens, particles of copper and cuprous oxide are visible in a separate state.

I am of opinion that these are artificial crystals of "Specular Iron," which have separated out on cooling from the molten slag, and crystallized in a sort of skeleton network, the interstices mechanically imprisoning the particles of copper and cuprous oxide which are present.

A small quantity of lime was added to the charge for the purpose of combining with and fluxing the Ferric Oxide; but no lime was found in the crystals.

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

No. 23. NOVEMBER, 1882. Vol. V.

*On some Minerals from the Sodalite-Syenite in Juliane-haab district, south Greenland.**

By Joh. Lorenzen.

Communicated by Prof. Johnstrup.

Read December 14th, 1881.

It is well known to mineralogists, that *Giesecke*, who in the years 1806—13 travelled in Greenland, brought home from Julianehaab district some new minerals, which he handed over to the Copenhagen Museums. In 1853-4 *Dr. Rink* supplied the museum of the Copenhagen University with a large collection of the same minerals, mostly in large and fine specimens, and the same collections have lately received a most valuable and considerable addition, through the travels of *Mr. K. J. V. Steenstrup* of the Danish Geological Survey of Greenland. Some of these interesting minerals, occurring in the Syenite on both sides of the fjords Tunugdliarfik and Kangerdluarsuk, have already long been known, whereas others had either been not found there before or at least not analysed or described.

As better materials for the examination of the minerals than those which were at the disposal of former investigators are now available, I have at the suggestion of Professor Johnstrup, undertaken the following examination.

The chief constituents of the Sodalite-syenite, the name of which is due to *Mr. Steenstrup*, are a greenish-white *felspar*, *arfvedsonite* (and

* Translated from Meddelelser fra Grönland, 2det Hefte, Kjoebenhavn, 1881, where a French resumé is given.

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ægirine) together with *sodalite*†. In some places the minerals assume very considerable dimensions, especially the arfvedsonite. The chief accessory is *eudialyte*, the garnet-like colour of which, when occurring in larger quantity, gives to the rock a reddish-brown tinge; more scarcely are found crystallized *nepheline* and two new minerals mentioned below. There likewise occurs, at single spot, crystallized *lievrite*, together with calcareous spar, and finally some zeolites, in particular analcime and natrolite. A circumstance which gives this rock a peculiar interest is, that most of the minerals above mentioned are found connected in a very similar way in the south of Norway, viz: in the syenite of the Langesunds fjord, where also occur arfvedsonite, ægirine, sodalite, nepheline (elæolite), eudialyte (eukolite), analcime and natrolite (brevicite).

I have examined most of the constituents of the sodalite-syenite, and perhaps it will not be out of place briefly to mention some former investigations. Firstly we find published a series of analyses of the *arfvedsonite* from Kangerdluarsuk, and no analysis of the *ægirine* from the same locality, but in the following it will be shown that the materials analysed in all cases have been either ægirine, or a mixture of arfvedsonite and ægirine The *eudialyte* is the best known of these minerals, but I have found that it contains a small quantity of cerium not indicated in the former analyses, which perhaps may be of some interest, an equal quantity having been found in the corresponding Norwegian mineral *eukolite*. As to the *sodalite*, the former analyses show clearly that the substance cannot have been fresh.

I shall now detail the several investigations.

I. Felspar.

The felspar occurs in greenish-white masses, often of perfect cleavage. In thin plates it is almost transparent. Under the microscope it has proved to be a microcline. The composition is:—

SiO_2	..	..	62·74
Al_2O_3	..	..	19·60
Na_2O	..	..	3·56
K_2O	..	..	13·09
			98·99

II.—Arfvedsonite.

Literature: Annnals of Phil., 1823 (Brooke). — Berz. Jahresber. 1825, 149 (Arfvedson).—Annales des mines 1832, T., I., 192 (Thomson)—Journ. f. pr. Ch. 13, 3, and 91, 449 (Kobell).—Pogg. Ann. 105, 292 and

† For further communications, maps, etc., see the paper of *Mr. Steenstrup*, in Meddelelser fra Grönland, etc.

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306 (Rammelsberg).--Zeitsch. f. Kryst. u. Min., IV. 94 (Doelter).—Berg— u. Hüttenmann. Zeitung 1865-66, (separately printed as: *mineralogische Studien* v. Aug. Breithaupt).

The arfvedsonite, the first name of which was "ferriferous hornblende," was distinguished by *Brooke* in 1823 as a peculiar mineral species. He did not examine the chemical composition, which indeed has not since been fully understood. The angle of cleavage he found to be 123° 55·. *Mitscherlich* likewise showed it to be the same as that of hornblende, and finally an analysis by *Arfvedson* seemed to show a conformity in its chemical composition.

Later on, the cleavage was examined by *Breithaupt*, and the chemical composition by *Thomson*, but although his analysis differs considerably from Arfvedson's, he has not observed the most characteristic peculiarity, finding no soda, but instead of this 8 per cent. manganous oxide.

That these analyses cannot have been made on veritable arfvedsonite, and so must be set aside, is now most evident, newer ones having been made by *Kobell* (I.), *Rammelsberg* (II.), and *Doelter* (III), as follows.

	I.	II.	III.
Cl. ..	0·24	—	—
SiO_2 ..	49·27	51·22	52·22
Al_2O_3 ..	2·00	trace	0·64
Fe_2O_3 ..	14·58	23·75	28·15
FeO ..	23·00	7·80	5·35
MnO ..	0·62	1·12	0·54
CaO ..	1·50	2·08	2·19
MgO ..	0·42	0·90	1·45
Na_2O ..	8·00	10·58	10·11
K_2O ..	—	0·68	0·34
Loss by heat	—	0·16	—
	99·63	98·29	100·99

It will be seen that the analysis of Kobell differs considerably from the others, between which the difference is not greater than will be often found in analyses of minerals, of which material of absolute purity cannot be secured.

Already in 1866 *Breithaupt*, by mere crystallographic investigation, made the observation that several minerals in collections are called arfvedsonite incorrectly, and with respect to this he says: "von allen scheint in die Sammungen am häufigsten ein Pyroxen, nämlich der Aigirin, als Arfvedsonit zu existiren ‡." This remark however has not had any influence on the position of *arfvedsonite* in the system.

‡ l. c., page 50.

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The arfvedsonite occurs at Siorarsuit and Kangerdluarsuk, partly massive, partly crystallized. The crystals, which have not before been described, are seldom found, but sometimes they attain a considerable development. The biggest crystal in the museum of the University is c. 9 inches long and c. 3½ inches in diameter; the terminating planes however are missing in this crystal; this often is the case on account of the growing together of the arfvedsonite with other minerals in the sodalite-syenite. The colour of fresh crystals is dark, but often they are grey, owing to an alteration on the surface; still a fracture shows the dark colour. The surfaces most frequently are dull, so that reliable measurements cannot be made. The prismatic and pinacoid planes are the best reflecting, whereas I could not measure the angle between a terminal plane and a pinacoid by the reflecting goniometer on more than one crystal. The rest of the angles are measured by the hand goniometer, but the planes being often very small, the measurements cannot be very precise. The result of the examination is that many of the characteristic forms of the amphibole are found to occur in the arfvedsonite.

Most commonly combinations of ∞ P and ∞ P̆ ∞. P and 2 P̆ ∞, are found. I have further found oP on a single crystal. Twins occur with the orthodome as composition-face.

The following angles were obtained by the reflecting goniometer:—

	∞ P	= 123°37′	— 124°48′
2 P̆ ∞	: ∞ P̆ ∞	= 119°48′	
∞P	: ∞ P̆ ∞	= 117°38′	

From the two last is calculated.

2 P̆ ∞	: 2 P̆ ∞	= 120°24′
	∞ P	= 124°44′

The most exact measurement, however, may be made on the cleavage-faces, which frequently are excellently reflecting. On such the angle was found to be 124°22′.

By the hand-goniometer we obtain:—

P : P = c. 148° P : 2 P̆ ∞ = c. 150°

One thing is especially worth remarking:—the crystals are *never striated.*

The massive arfvedsonite is either dark and breaks easily,—the cleavage-faces then are both distinct and reflecting—or it is somewhat greyish. In the last case the cleavage-faces become more dull, the coherence more solid, and the mineral penetrated with small fissures, which are filled with a whitish mineral. The substance used for the analysis was taken from the first variety, large massive specimens of which are preserved in the

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museum; besides it is also found adherent to ægirine, eudialyte and sodalite.

Cleavage-faces: the prismatic and pinacoid planes; the last being more distinct than the corresponding ones of amphibole.

The fracture sometimes is conchoidal, often vitreous in lustre.

Streak and powder *dark-blue grey*, a very important distinction between it and ægirine.

Hardness between that of felspar and that of apatite. Specific gravity 3·44 (*Brooke* also found 3·44).

Fuses easily and forms vesicles in a Bunsen's gas lamp without the use of the blowpipe. Yields a dark magnetic bead.

For the chemical analysis the above mentioned dark massive arfvedsonite was used, which, when carefully selected, might be obtained very pure, and the analysis was effected in the usual manner. The iron oxide and sesquioxide were separated according to the method indicated by *Doelter*, (Fres. Zeits. f. analyt. Chemie 18 Jahrg. P. 50), viz: the mineral is decomposed by a mixture of hydrofluoric and sulphuric acids, in an atmosphere of carbonic acid, and the solution titrated with permanganate of potash. Three titrations gave accordant results.

SiO_2	43·85	0·731		0·731
Al_2O_3	4·45	0·044		
Fe_2O_3	3·80	0·024		0·068
FeO	33·43	0·464		
MnO	0·45	0·006		
CaO	4·65	0·083		
MgO	0·81	0·020		0·716
Na_2O	8·15	0·132		
K_2O	1·06	0·011		
Loss by heat	0·15			
	100·80			

From the analysis is then obtained:—

$$R : R : Si = 0{\cdot}716 : 0{\cdot}068 : 0{\cdot}731$$
$$= 10{\cdot}53 : 1 : 10{\cdot}75$$
$$= 11 : 1 : 11$$

which affords the formula:—

$$11\,R\,SiO_3 + R_2O_3.$$

Further:—

$$Fe\,(Mn) : Ca\,(Mg) : Na_2(K_2) = 0{\cdot}470 : 0{\cdot}103 : 0{\cdot}143$$
$$= 14 : 3 : 4$$

which approximatively affords:—

$$\left.\begin{matrix} 4\,Na_2\,SiO_3 \\ 3\,R\,SiO_3 \\ 14\,R_1\,SiO_3 \end{matrix}\right\} + 2R_2O$$

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where $Fe_2 : Al_2 = 1 : 1{\cdot}8$. The above formula gives the following composition:—

$21SiO_2$	1260	SiO_2	43·04
$\frac{4}{3}Al_2O_3$	137·33	Al_2O_3 ..	4·68
$\frac{2}{3}Fe_2O_3$	106·66	Fe_2O_3 ..	3·64
14FeO	1008	FeO	34·43
3CaO	168	CaO	5·74
$4\,Na_2O$	248	Na_2O ..	8·47
	2927·99		100·00

It will be seen that neither my analysis nor the formula agrees with the former ones. I was surprised to find almost the whole quantity of iron present as protoxide, but the smaller quantity of silica and the rather considerable amount of alumina are also remarkable. To explain this difference it may not be out of place to state and consider what former investigators say about the substances used for their analyses.

Kobell had obtained a specimen from one of Giesecke's collections, on which the arfvedsonite was adherent to eudialyte. The description of its appearance accords with that of the arfvedsonite; unfortunately he does not mention, whether he has used a crystal or a massive specimen, nor does he give the specific gravity. Still he is surprised (Journ. f. pr. Ch. 91, 450,) by the difference between his analysis and that of *Rammelsberg*, who does not state the angle of cleavage obtained by his own measurements. The specific gravity he states to be 3·589, which is somewhat more than that of the arfvedsonite; further he says: "der Arfvedsonit, welchen ich zur Analyse benutzte, bildete *stark gestreifte, am Ende zerbrochene Prismen*," (it will be remembered the arfvedsonite never occurs as such; but the description strikingly agrees with ægirine) and he continues; "und war mit Eudialyt und Sodalith stark verwachsen."

Doelter says, that the angle of cleavage places the mineral in the amphibole-group, but then he adds: "an den mir vorliegenden Stücken von Arfvedsonit, der mit Eudialyt vergesellschaftet war, fand ich nur Krystallen ohne Endflächen, die die Combination des Prismas mit einer Längsfläche zeigten. *Die starke vertikale Riefung gestattete keine Messung mit dem Reflexions-goniometer.*"

The museum of the university now possesses a great many specimens, with which the descriptions of *Doelter* and *Rammelsberg* agree very well, if one single alteration be made; viz: *to put the name of ægirine in the place of arfvedsonite.* That the angle of cleavage nevertheless is found by Doelter to be the same as that of amphibole, is easily explained by the circumstance, that arvedsonite and ægirine often are very closely grown together, and as the cleavages are more distinct in arfvedsonite than in

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ægirine, these have been determined by the first, although it may perhaps have been in small quantity.

The arfvedsonite has hitherto held an isolated place in the system, but can now be referred to the general formula of aluminiferous amphibole, which *Rammelsberg* has adopted in the last edition of his Mineralchemie, viz:

$$\left\{\begin{matrix} m\,R\,SiO_3 \\ n\,R\,O_3 \end{matrix}\right\}$$

III. Ainigmatite.

Several crystals of this mineral, which firstly was determined by *Breithaupt** are preserved in our museum, and have been found at Naujakasik. Their form is monoclinic, and at the first look they seem to resemble the arfvedsonite. The general combination is ∞P, $\infty \breve{P} \infty$, $\infty \breve{P} \infty$, together with a pyramid and two sets of planes, which, as the base is absent, cannot be rigorously determined. Perhaps they are clinodomes. The orthopinacoid plane is very characteristic, this plane not being developed on arfvedsonite. Further, the two minerals differ considerably in other respects, which will be evident from the following properties of the ainigmatite.

Prismatic angle (measured with hand-goniometer) = 114°.

Streak reddish-brown.

Specific gravity of a perfect, small, tolerably pure crystal was found = 3.80.

Still the two minerals resemble each other, as both are dark coloured and have the hardness = 5.5. If the streak is not tried or the prismatic angle not measured, one is easily mistaken. An analysis of the ainigmatite was not undertaken, as the few crystals in the museum do not seem to be pure enough to give a satisfactory result.

Together with the ainigmatite *Breithaupt* has mentioned an isomorph mineral, *Koelbingite*, which differs from the first by a green streak and a smaller specific gravity; he supposes the ainigmatite to be pseudomorphous from the koelbingite. To which I shall merely remark, that our museum does not possess any koelbingite, but several crystals of ainigmatite, which being all very fresh and unaltered, can scarcely be admitted to be pseudomorphous.

IV. Ægirine.

Literature, Pogg. Ann. 61, 543 (Scheerer). 80, 314 (Plattner & Breithaupt) 103, 286 and 302 (Rammelsberg), 122, 118 (Rube & Gutzkow). Comptes Rendus 56, 846 (Pisani).—Zeits. f. Kryst. Min. IV, 91 (Doelter).

* l.c. P. 51.

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Ægirine till now has been known chiefly as an augitic mineral from Brevig, showing a remarkable resemblance in chemical composition to arfvedsonite. That this, with respect to the last, was not correct, has already been stated above.

The specific gravity of the Norwegian ægirine is stated by *Breithaupt* to be 3.432—3.504; by *Rammelsberg* 3.578 and the prismatic angle 86°52′. I give here the analyses of *Rammelsberg* (I), *Pisani* (II), Rube (III).

	I.	II.	III.
TiO_2 ..	— ..	— ..	1.06
SiO_2 ..	50.25 ..	52.11 ..	50.03
Al_2O_3 ..	1.22 ..	2.47 ..	0.55
Fe_2O_3 ..	22.07 ..	22.80 ..	28.68
FeO ..	8.80 ..	8.40 ..	1.98
MnO ..	1.40 ..	— ..	1.52
CaO ..	5.47 ..	2.60 ..	1.42
MgO ..	1.28 ..	0.41 ..	1.33
Na_2O ..	9.29 ..	12.10 ..	12.20
K_2O ..	0.94 ..	— ..	—
Loss by heat	— ..	0.30 ..	1.05
	100.72	101.19	99.82

Ægirine is found at Kangerdluarsuk, Siorarsuit and Kumernit, grown together with eudialyte, sodalite and arfvedsonite. Often the arfvedsonite is coated with crystallized ægirine, which may very easily mislead in the determination of the minerals, the streak however immediately shows the difference. The mineral generally occurs in distinct, broken crystals, much striated along the axis, nearly always unaltered and with a certain metallic lustre. Some few non-striated crystals are also found, such as may be measured by the reflecting goniometer. On some crystals I found besides the fundamental pyramid, a very acute pyramid, and two clinodomes, the angles of which I was not able to measure by the hand-goniometer on account of the smallness of their planes. The general combination is ∞P. ∞P∞. ∞P∞. P. By the reflecting goniometer ∞P=86°58′—87°6′ and P : ∞P=120°51′ were found. By the hand-goniometer the angle between the polar edge of the pyramid and ∞P∞ was found to be c.105°. These angles agree with those of augite.

The cleavage is prismatic, not so well developed as in the arfvedsonite, still it is easily observed when a polished face of the mineral is turned in the sunlight.

Streak and powder, light green.

Hardness, 5.5—6. Specific gravity, 3.63.

Fuses easily before the blowpipe to a dark magnetic bead. Is not decomposed by acids.

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For the chemical analysis a fresh crystal was used, which under the microscope had proved to be very pure. The oxides of iron were determined as with arfvedsonite. The analysis yielded the following results:

		Quotients.	
SiO_2	49.04	0.818	0.818
Al_2O_3	1.80	0.017	0.201
Fe_2O_3	29.54	0.184	
FeO	4.82	0.067	
MnO	trace	—	0.115
CaO	2.70	0.048	
MgO	trace	—	
Na_2O	13.31	0.215	0.215
K_2O	trace	—	
	101.21		

$Na_2 : R = 0.215 : 0.115$
$= 2 : 1$

$R : R = 0.201 : 0.115$
$= 1.75 : 1$
$= 2 : 1$

$R : Si = 0{\cdot}108 : 0{\cdot}815$
$= 1 : 7{\cdot}6$
$= 1 : 8$

Hence the formula:

$$Na_4 R R_2 Si_8 O_{22}$$

or

$$\left\{ \begin{array}{l} 2\ Na_2 SiO_3 \\ R\ SiO_3 \\ R_2 Si_5 O_{16} \end{array} \right\}$$

wherein Ca : Fe = 2 : 3 $\quad$ $Al_2 : Fe_2 = 1 : 11$

then:	$8\ SiO_2$	= 480	SiO_2	49·03
	$2\ R_2O_3$	= 310	R_2O_3	31·66
	RO	= 65	RO	6·64
	$2\ Na_2O$	= 124	Na_2O	12·67
		979		100·00

The ægirine examined is therefore a mixture of bisilicates, in which, however, the sesquioxides form a basic salt.

The analysis of *Rammelsberg*, which does not at all agree with *Pisani's* or with *Rube's* leads to the formula.

$$\left\{ \begin{array}{l} 6\ Na_2 SiO_3 \\ 10\ R\ SiO_3 \\ 5\ Fe_2 Si_2 O_9 \end{array} \right\}$$

The small quantity of soda and the large quantity of lime are striking; perhaps therefore it may be supposed that the substance used for his analysis was not very fresh.

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V. Sodalite.

Literature of the Greenland sodalite: Ann. of. phil. I, 104 (Ekeberg) Gilbert's Ann. 39, 127 and 40, 98 and Journal des Mines 1811 (Thomson). Pogg. Ann. 109, 576 (Rammelsberg.)

Sodalite was first found in Greenland, and was by the *Count de Bournon* considered to be a green felspar; in 1811 the mineral was named by *Thomson* with especial regard to the great quantity of soda contained in it. He finds in the mineral two p. ct. of water, but only a small quantity of chlorine, which shows that the substance analysed by him cannot have been either very pure or fresh. I give the analyses of *Thomson* (I) and *Ekeberg* (II) together with an analysis of an unaltered sodalite from Ilmengebirge by *G. Rose* and *E. Hofmann* (III) for comparison with mine.

	I.	II.	III.
SiO_2 ..	38·52	36·00	38·40
Al_2O_3 ..	27·48	32.00	32·04
Fe_2O_3 ..	1·00	0·25	—
CaO ..	2·70	—	0·32
Na_2O ..	23·50	25·00	24·47
Cl ..	3·00	6·75	7·10
Loss by heat	2·10	—	—
	98·30	100·00	102·33

Obviously the analysis of *Ekeberg* was made on a fresher substance than *Thomson's*, but it cannot be quite correct, as it does not show any surplus.

The sodalite is always coloured green, which under the microscope is seen to arise from an intermixture of microscopical crystals of arfvedsonite. The crystals are dodecahedra, imbedded in arfvedsonite or felspar, less frequently in eudialyte, and form, especially in the last case, a very beautiful rock.

The size of these dodecahedra is generally equal to that of a pea. The Museum however possesses some broken specimens, which are an inch in diameter; these are imbedded in felspar.

The fracture is conchoidal, with a vitreous lustre; the cleavage faces are parallel to the planes of the dodecahedra.

Hardness=5·5—6. Specific gravity=2·31.

Before the blowpipe it does not fuse so easily as the Vesuvian sodalite, and becomes grey and opaque.

At first it seemed somewhat difficult to isolate the substance, but I always preferred to take the sodalite which was imbedded in arfvedsonite, these two minerals being distinctly separated through the difference in colour. Still a complete separation is impossible, the sodalite, as above

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mentioned, being penetrated with microscopic crystals of arfvedsonite, but fortunately also unnecessary, as on solution in hydrochloric acid the whole quantity of felspar and of arfvedsonite remain unaltered and can be filtered from the solution.

If the mineral be dissolved in nitric acid, the chlorine can very easily be determined; there are but one or two milligrams of silica precipitated with the chloride of silver. The analysis yielded the following result:

		Quotients.	
SiO_2	36·50	0·608	0·608
Al_2O_3	31·53	0·306	0·309
Fe_2O_3	0·19	0·003	
CaO	0·25	0·004	0·430
Na_2O	26·30	0·424	
K_2O	0·18	0·002	
Cl	7·30	0·206	0·206
	102·25		

then

$$Na : Cl = 0{\cdot}848 : 0{\cdot}206 \qquad Al_2O_3 : SiO_2 = 0{\cdot}309 : 0{\cdot}608$$
$$= 4{\cdot}1 : 1 \qquad = 1 : 2$$

$$Na_2 : Al_2 = 0{\cdot}424 : 0{\cdot}309$$

if the quantity of sodium contained in Na Cl be subtracted, we have:

$$Na_2 : Al_2 = 0{\cdot}319 : 0{\cdot}309$$
$$= 1 : 1$$

and obtain the formula

$$\left\{ \begin{array}{c} 2\ Na\ Cl \\ 3\ Na_2\ Al_2\ Si_2\ O_8 \end{array} \right\}$$

the same as stated in *Rammelsberg's* Mineralchemie. The formula yields the following result:

6 Si	= 168	SiO_2	37·08
3 Al_2	= 163·8	Al_2O_3	31·71
8 Na	= 184	Na_2O	25·55
24 O	= 384	Cl	7·31
2 Cl	= 71		
	970·8		101·65

VI.—Nepheline.

The Greenland Nepheline is found at Naujakasik and Siorarsuit in Tunugdliarfik, on the northern side of Nunasarnausak, and at Kangerdluarsuk: it has not till now been examined. It occurs crystallized in hexagonal prisms, terminated by the basal pinacoid; and very seldom in combination with small planes belonging to the first pyramid. The crystals are greyish white or greenish, in the last case translucent on the edges; they are seldom larger than a hazel-nut, and frequently smaller; the surface is coated with small shining laminæ of mica. It also occurs massive, closely connected with arfvedsonite and felspar,

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and very much resembling sodalite. In this form it was found on a specimen from which in the course of time part of the nepheline had disappeared, leaving in the ground mass of arfvedsonite and felspar, larger and smaller cavities, the form of which reminded of crystals of sodalite, so that I considered it to be sodalite until I had analysed the mineral. This mineral however sometimes has pretty distinct cleavage-faces, and, if these are missing, a sort of conchoidal fracture,—the conchoidal face being very small,—which has vitreous lustre; on the other hand, on the nepheline I have never seen distinct cleavage-faces, but an uneven or splintery fracture and a greasy lustre. To decide whether a specimen be the first or the second, it is always sufficient to to dissolve a bit in nitric acid and search for chlorine.

The specific gravity of the crystal used for analysis I, was 2·60, that of the massive mineral 2·63. Moreover it must be remarked, that, although the crystal also contained a small quantity of arfvedsonite and felspar, the massive mineral contained thrice as much. In the first analysis, the crystal did not yield substance enough for the determination of the water. The second analysis was made on the massive mineral. Of course the alumina was in both cases purified from silica. The following results were obtained.

	I.	Quotients.	II.	Quotients.
SiO_2	43·39	0·723	41·87	0·698
Al_2O_3	32·28	0·313	33·94	0·335
Fe_2O_3	0·92	0·005	0·70	0·004
CaO	0·70	0·012	0·47	0·008
K_2O	5·62	0·060	6·68	0·071
Na_2O	16·52	0·266	15·03	0·243
Cl	Trace		Trace	
Loss by heat	——		0.94	
	99·43		99·63	

There is some difference between the analyses. Perhaps it might be supposed that, when the nepheline in II was dissolved in hydrochloric acid, a small quantity of silica had remained with the felspar and arfvedsonite, and had been filtered from the solution along with these. In fact, the whole residue was more unhesitatingly set down as undecomposed mineral, because at the beginning of the analysis I supposed the mineral to be altered sodalite, whith might be fully and easily dissolved in hydrochloric acid. I will therefore take both minerals into consideration when calculating the formula.

	$R_3 + R_1$	:	Si	R_2	:	R	K	:	Na
I	0·656	:	0·723	0·338	:	0·318	0·060	:	0·266
	= 1	:	1·1	1·06	:	1	1	:	4·4
II	0·661	:	0·698	0·322	:	0·339	0·071	:	0·243
	= 1	:	1·05	1	:	1·05	1	:	3·4

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If we venture to change the ratio to :—

$R + R : Si = 1 : 1 \quad R_2 : R = 1 : 1 \quad K : Na = 1 : 4$

It will afford the plain formula.

$$R_2SiO_3 + Al_2SiO_5 = R_2Al_2Si_2O_8$$

And the composition will be

2 SiO_2	=	120·	SiO_2	=	41·18
Al_2O_3	=	103·	Al_2O_3	=	35·35
$\frac{1}{5}$ K_2O	=	18·8	K_2O	=	6·45
$\frac{4}{5}$ Na_2O	=	49·6	Na_2O	=	17·02
		291·4			100·00

The above formula is the same which *Rammelsberg* formerly admitted, but has now given up. It is exactly the same as that of the silicate in sodalite, while the formula which *Rammelsberg* prefers is that of the silicate in sodalite-leucite. It is true that in the formula here used there is the drawback that it gives too small a quantity of silica and too much of the bases, but on the other hand it seems preferable on the ground of simplicity.

VII.—Eudialyte.

Literature: Crells chem. Ann. I, 493. 1801 (Trommsdorf). Gilbert's Ann. 13,491. 1803 (Gruner) and 63,379. 1819 (Stromeyer). Schweigger's Beiträge z. Chem. u. Phys. 29,1. 1820 (Pfaff). Pogg. Ann, 63, 142. Oefvers. Sv. Vet. Ak. Forh., 1845, 37 (Svanberg).—Comptes Rendus 43, 1197 (Damour).—Acta. Univ. Lund. II., 1—25, 1870 (Nylander).

Eudialyte, which on account of its colour and whole appearance, resembles somewhat both garnet, and zircon, was first examined by *Trommsdorf*, who, in 1801 found Zirconia in it, and gave it the name "dichter Hyacinth." A few years later *Gruner* mentions, that the Prince *Galitzin* has referred it to coccolite, which recently had been discovered by *Abildgaard*, but to that *Gruner* objects, since coccolite contains manganese dioxide, eudialyte zirconia. He proposes the name "blättrige-Hyazinth," although the mineral in the title of his paper is called "der rothe blättrige Granat aus Groenland." In 1819 finally *Stromeyer* made an analysis more trustworthy than the previous ones, and called it by the name of eudialyte, because it is easily dissolved in acids; and this name has remained unaltered. A contemporaneous analysis was instituted by *Pfaff*, but all these analyses are now superseded by newer ones, instituted by *Rammelsberg* (I), *Damour* (II), and *Nylander* (III).

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	I	II	III
TaO_2	——	0.35	——
SiO_2	49·92	50·38	51·86
ZrO_2	16·88	15·60	14·67
FeO	6·97	6·37	6·54
MnO	1.15	1·61	1·46
CaO	11·11	9·23	9·82
Na_2O	12·28	13·10	12·32
K_2O	0·65	——	——
Loss by heat	0·37	1·25	1·43
Cl	1·19	1·48	1·37
	100·52	99·37	99·47

In his report on an investigation of larger quantities of eudialyte, *Svanberg* mentions, but without adding a quantitative analysis, that the Greenand eudialyte contains besides the oxides of the cerium group, two other oxides, one of them resembling yttrium.

The eudialyte, as is well known, is found partly massive, partly crystalized. The crystals almost always show a great many planes. Still I have not been able to discover others than those already mentioned in the Mineralogy of *Des Cloizeaux*. The cleavage faces corresponding to $\frac{1}{2}$ R, and the base are distinct, the cleavage formerly indicated as being indistinct is not easily discovered. The fracture is granular to conchoidal, and exhibits a strong vitreous lustre.

Hardness 5·5. Specific gravity 2·85.

The streak is white, still, the powder has a faint rose colour, which is scarcely observable in the streak.

Before the blowpipe it fuses pretty easily to a green glass. When treated with acids it gelatinizes, evolving a distinct odour of sulphuretted hydrogen.

Three analyses were made besides two determinations of chlorine and two of water. To determine the chlorine I distilled the mineral with diluted sulphuric acid, and precipitated the chlorine in the distillate. The water was at first determined as loss by heat; the second time by direct weighing in a tube with calcium chloride.

The silica always contains a considerable portion of the zirconia. This was dissolved in sulphuric acid, and, after evaporation, was added to the filtrate from the silica. The filtrate was precipitated by ammonia, and the precipitate having been dissolved in hydrochloric acid, the zirconia was precipitated by sodium hyposulphite. In the filtrate the cerium oxides were thrown down by oxalic acid, and in the filtrate from the last precipitate the iron oxide by ammonia. The precipitate of the cerium oxide agreed perfectly with the usual reactions of this substance.

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The result of the analysis was as follows :—

		Quotients.	
SiO_2 ..	48·63 ..	0·811 }	0·930
ZrO_2 ..	14·49 ..	0·119 }	
FeO ..	5·54 ..	0·077 }	
MnO ..	0·42 ..	0·006 }	
CeO (LaO, DiO)	2·27 ..	0·021 }	0·297
CaO ..	10·57 ..	0·189 }	
MgO ..	0·15 ..	0·004 }	
Na_2O ..	15·90 ..	0·256	0·256
K_2O ..	trace ..	—	
Cl ..	1·04 ..	0·030	0·030
Water ..	1·91 ..		
	100·92		

Then Cl : Na = 0·030 : 0·512 = 1 : 17·1
Na_2 : R = 0·256 : 0·297 = 0·86 : 1
If the NaCl be substracted = 0·8 : 1
Or approximately = 1 : 1
R : (Zr,Si) = 0·297 : 0·930, Zr : Si = 0·119 : 0·811
= 1 : 3·1 = 1 : 6·8

This ratio affords tolerably correctly the formula:

$$NaCl + 8\ Na_2\ R\ (Si,Zr)_6\ O_8$$

or

$$\left\{ \begin{array}{c} NaCl \\ 8 \left\{ \begin{array}{ll} Na_2 & (Si,\ Zr)_2\ O_5 \\ R & (Si,\ Zr)\ O_3 \end{array} \right. \end{array} \right\}$$

Further we have :

Ce : Ca = 0·021 : 0·189. Fe : Ca = 0·077 : 0·189
= 1 : 9 = 1 : 2·5

The formula differs somewhat from that which may be deduced from the analyses of *Rammelsberg* and *Nylander*, (with which that of *Damour* does not agree), according to whom eudialyte has the following composition :—

$$\left\{ \begin{array}{c} NaCl \\ 6 \left\{ \begin{array}{ll} Na_2 & (Si,\ Zr)_2\ O_5 \\ R_2 & (Si,\ Zr)\ O_3 \end{array} \right. \end{array} \right\}$$

containing a much smaller quantity of soda, but more zirconia and silica, which perhaps is owing to a less fresh substance.

VIII.—Lievrite.

The Greenland Lievrite* here described for the first time, occurs both massive and crystallized. The colour is in both cases dark; the crystals are quite fresh and show an intense metallic lustre. They occur in highly striated prisms, the terminal planes are often missing, because the crystals have grown to other minerals; but are also

* On the occurrence of lievrite and lepidolite in Greenland, see the remarks of Prof Johnstrup, p. 69

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frequently well developed. The common combination is $\infty \breve{P} \infty$, $\bar{P} \infty$, $\frac{3}{2} \breve{P} \infty$ connected with some more indistinct prisms. Besides the brachydome $\frac{3}{2} \breve{P} \infty$ is commonly seen a curved plane, continuing the pinacoid—consisting of some more brachydomes. On several crystals is the fundamental pyramid associated with these in very small planes, commonly striated parallel to the long polar edge, and in this case not to be accurately measured; I therefore give but one measure, taken from the most distinct crystal. All the angles were measured by the reflecting goniometer, and have yielded the following results, with regard to which it should be remarked that the prismatic angle could not be measured exactly on account of the striation, and therefore I do not state its measurements.

		Des Cloiseaux
$\bar{P} \infty : \bar{P} \infty$	= 112°46′—112°49′	112°49′
$\frac{3}{2} \breve{P} \infty : \frac{3}{2} \breve{P} \infty$	= 96°6′	96°57′
$P : P$	= 139°29′	139°31′

Often the crystals are twins, with the brachy-pinacoid the composition-face. The streak and powder are coal black.

The hardness is 6, parallel to the longer-axis of the crystals, vertically to this direction, 5·5. Specific gravity 4·05.

Before the blowpipe the mineral fuses pretty easily. Is easily dissolved in acids.

When heated in a small combustion-furnace, it lost only a small quantity of water. As late analyses by *Sipocz*† and *Staedeler*‡ have shown contrary to the previous supposition, that lievrite contained water chemically combined, it was necessary to see if this could be admitted for the Greenland lievrite. The crystals which were at my disposal were excellently fit for this investigation, being intensely shining and showing a fresh dark fracture; that these should have taken up water in consequence of some alteration, seemed altogether impossible. Two examinations were made; the first time the lievrite was heated in a platinum tube, the second time in an iron tube well heated beforehand in a combustion furnace; both tubes were about $\frac{3}{8}$ inch in diameter and eighteen inches long. The powdered lievrite was placed in a small platinum boat and introduced in the tube, which was now heated before the blowpipe, while a current of dry air passed through the tube. The water expelled was collected in a tube filled with calcium chloride and weighed. This method is the same as that which was used by *Sipocz*. I found respectively 1·71 and 1·90 p.ct. of water. When heating the last time, I obtained a higher temperature, and I therefore think the figure 1·90 is to be preferred.

† Tschermak, Mineralog., Mittheilungen 1875, 71.
‡ Journal f. prakt. Chem. 99, 70.

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The result was as follows :—

		Quotients.	
SiO_2 ..	29·30 ..	0·488 ..	0·488
Fe_2O_3 ..	20·30 ..	0·127 ..	0·127
FeO ..	33·50 ..	0·465 } ..	0·493
MnO ..	1·97 ..	0·028 }	
CaO ..	13·71 ..	0·245 ..	0·245
Loss by heat	1·90 ..	0·106 ..	0·106
	100·68		

Then $Ca : (Fe\,Mn) : Fe_2 : Si = 0{\cdot}245 : 0.493 : 0{\cdot}127 : 0{\cdot}488$

$= 1{\cdot}94 : 3{\cdot}9 : 1 : 3{\cdot}84$

$= 2{\cdot} : 4 : 1 : 4{\cdot}$

and $H_2 : Fe_2 = 0{\cdot}106 : 0{\cdot}127$

$= 1 : 1{\cdot}2$

This ratio affords the formula :—

$$\left\{\begin{matrix} 2\,Fe_2\,Si\,O_4 \\ Ca_2\,Si\,O_4 \\ Fe_2\,Si\,O_5 \end{matrix}\right\} + H_2\,O$$

or $H_2\,Fe_4\,Fe_2\,Ca_2\,Si_4\,O_{18}$

Whence the following composition is deduced :—

4 Si O_2	= 240 ..	Si O_2 ..	29·34
Fe_2O_3	= 160 ..	Fe_2O_3 ..	19·56
4 Fe O	= 288 ..	Fe O ..	35·21
2 Ca O	= 112 ..	Ca O ..	13·69
H_2O	= 18 ..	H_2O ..	2·20
	818		100·00

The above formula is the same which the analyses of *Sipocz and Staedeler* yielded.

IX.—Lepidolite.

Lepidolite occurs together with ægirine, arfvedsonite, eudialyte, sodalite, and the following mineral at Kangerdluarsuk. It here exhibits two axes of double refraction. The colour is white, it forms very shining laminæ, in several places intermixed with very small crystals of ægirine, in other places quite pure. The hardness is 2·5, the specific gravity 2·81.

When heated, it fuses very easily (in a candle-flame) to a white bead and communicates to the flame a red colour. It is not decomposed by acids, not even by boiling concentrated sulphuric acid. It contains water in great quantity, but no fluorine. For this I have carefully searched by fusing the mineral with sodium carbonate, and proceeding in the usual way. When calcium chloride had been added, a small precipitate was obtained, but it proved to be only carbonate of calcium.

The lepidolite used for the analysis was extremely pure. The beginning of the analysis was conducted in the usual manner. The

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alumina being precipitated, the filtrate contained the sulphates of the alkalies. When by evaporating and heating they had been separated from the salts of ammonia, they were dissolved, and the sulphuric acid was precipitated by calcium-chloride and alcohol. In the filtrate the lime was precipitated by oxalic acid, and the alkalies were weighed as chlorides. The chlorides were treated by a mixture of ether and absolute alcohol. The lithium chloride being thereby dissolved, the chlorides of sodium and potassium, remaining as residue, were separated by platinum tetrachloride.

To determine the quantity of water I heated the lepidolite before the blowpipe flame; as no fluorine was present, all the loss by heat might be set down as water. The lepidolite only very slowly lost all its water; until the 13th weighing I did not obtain a constant weight; the mineral had then been exposed to the heat for altogether 5 or 6 hours. In the crucible it fused instantly to clear beads of a vitreous lustre.

The result of the analysis was:—

SiO_2 ..	58·93 ..	—— ..	58·93 ..	0·982	0·982
Al_2O_3 ..	12·87 ..	12·79 ..	12·83 ..	0·125	0·132
Fe_2O_3 ..	1·04 ..	1·18 ..	1·11 ..	0·007	
K_2O ..	—— ..	5·37 ..	5.37 ..	0·057	0·482
Na_2O ..	—— ..	7·63 ..	7·63 ..	0·123	
Li_2O ..	—— ..	9·07 ..	9·07 ..	0·302	
Loss by heat —— ..	4·99 ..	4·99 ..	0·277	0·277
			99·93		

Then:—

$$Si : Al_2 : R_2 : H_2 = 0{\cdot}982 : 0{\cdot}132 : 0{\cdot}482 : 0{\cdot}277$$
$$= 7{\cdot}4 : 1 : 3{\cdot}7 : 2{\cdot}1$$

If we may assume the ratio to be:—

$$7 : 1 : 4 : 2$$

It will afford the plain formula:—

$$\left\{\begin{matrix} 4 & R_2 & Si & O_3 \\ & Al_2 & Si_3 & O_9 \end{matrix}\right\} + 2\,H_2O$$

Wherein $K : Na : Li = 1 : 2 : 5$.—

The formula shows this lepidolite to be a hydrate of bisilicates, but it does not, it is true, agree fully with the composition obtained by the analysis:—

$7\,SiO_2$	= 420 ..	SiO_2 ..	56·53
Al_2O_3	= 103 ..	Al_2O_3 ..	13·86
$\frac{1}{2}\,K_2O$	= 47 ..	K_2O ..	6·34
Na_2O	= 62 ..	Na_2O ..	8.34
$\frac{5}{2}\,Li_2O$	= 75 ..	Li_2O ..	10·09
$2\,H_2O$	= 36 ..	H_2O ..	4·84
	743		100·00

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This lepidolite has thus been proved to contain a much larger quantity of silica than the species of mica formerly known, and less than half of the quantity of alumina usually contained in lepidolite. Further, it contains unusual quantities of alkalies and of water, while the fluorine, which has been found in all other lepidolites, is wholly wanting.*

X.—Steenstrupine.

The analysis of this mineral has shown it to be a new species, and, as suggested by Prof. Johnstrup, I have therefore given it the name of *Steenstrupine*, after Mr. *Steenstrup*, who not only first found the mineral, but to whom the Museum is also indebted for the acquisition of excellent specimens of the numerous and rare minerals from the Julianehaabs district.

The mineral has a brown colour, a faintly brown, almost white, streak, The hardness is 4, and the specific gravity 3·38. It is pretty easily fused before the blowpipe to a grey, dull bead. Occurs massive and crystallized, together with lepidolite and ægirine in the sodalite-syenite at Kangerdluarsuk.

The crystals are almost always curved, or appear as if they were gnawed off both on the edges and on the planes; only on two small crystals have I been able to observe tolerably distinct planes and edges of combination. They have a certain resemblance to the crystals of eudialyte, and seem to be combinations of a rhombohedron and the basal pinacoid; to these on the above mentioned two small crystals, there are associated a second positive rhombohedron, and perhaps more than one negative. The angle between the base and the fundamental rhombohedron could not be accurately measured, but was found to be about 128°. As in eudialyte, it is 112° 18′, the two minerals cannot by any means be connected.

The chemical composition being somewhat intricate, I shall give a detailed account of the analysis. The mineral seems to be totally decomposed by acids; however, as it always contains a small quantity of ægirine, which cannot be separated from the silica, I preferred to treat the mineral as if it was not decomposable by acids. I made a single separate determination of the silica, and three analyses; in one of these the mineral was decomposed by carbonate of sodium, and in two by hydrofluoric acid.

* Compare *Reuter's* analysis of the lepidolite from Rozena: Fl 4·86, SiO_2 50·43, Al_2O_3 28·07, Mn_2O_3 0·88, MgO, 1·42, K O 10·59, Na_2 O 1·46, Li_2 O 1·23,—98·94, *Rammelsberg*, Mineralchemie 1875, 521.)

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The *silica* had a red-brown colour, somewhat resembling that of silica containing iron oxides. After having been heated it was brownish and proved to be extremely impure; 0·2795 gr. was once mixed with 0·234 gr. of the bases (total weight = the impure silica = 0·5135 gr.). The bases on being heated by themselves, were of a dirty grey colour, after cooling, brown. They were dissolved in sulphuric acid, except a small in soluble residuum, and the solution was added to the filtrate from the silica.

Decomposition by hydrofluoric and sulphuric acid.—The mineral was totally decomposed and dissolved, except a small residue, which before the blowpipe in a bead of ammonium-sodium phosphate remained uncoloured; it was further insoluble in sulphuric acid, and was supposed to be tantalic acid. The solution was precipitated with ammonium sulphide, the precipitate dissolved and again precipitated.

The precipitate was now dissolved in hydrochloric acid, which was expelled by sulphuric acid and concentration. The oxides of the cerium-group were then precipitated by sodium sulphate. The filtrate from this precipitate, being a concentrated solution of sodium-sulphate, was precipitated by ammonium-sulphide and the precipitate dissolved. The solution was boiled with sodium acetate, after which only the *manganese* remained in solution; this was determined in the usual manner. In the precipitate thorium and iron were separated from the *alumina* by soda. The *thorium* and *iron* were separated from one another by hyposulphite of sodium.

I have tried to separate the oxides of the cerium-group, in all the analyses, by the method of *Gibbs* (American Journ. 37, 252. 1864), according to which the oxides are oxidized by nitric acid and lead dioxide. Thereupon the basic salts are produced by warming and treated with water containing a small quantity of nitric acid, when the salts of lanthanum and didymium are dissolved, the cerium salt remaining.* I did not find the method practical, especially because it is at times almost impossible to filter the solution from the basic cerium salt. If the solution contains a certain quantity of lead nitrate, the filtration proceeds somewhat easier. For the rest I may remark, that after having been heated, the oxides of lanthanum and didymium were easily dissolved in water containing a drop of nitric acid, but the cerium oxide only when warmed with sulphuric acid, whereas when mixed together, as they were before the separation, they were easily dissolved in hydrochloric acid.

* Before this operation the sulphates of sodium and cerium, etc., were dissolved; the solution was precipitated by oxalic acid and the oxalates, when heated, dissolved in hydrochloric acid, which finally was expelled by nitric acid.

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The quantity of alumina is doubtful, some of it being always dissolved in hydrochloric acid with a yellow colour, which I have not been able to explain.

The *thoria* yielded the following re-actions:—

[1] With *tannic acid*, no precipitate and no colour,

[2] With *zinc and sulphuric acid*, no precipitate and no colour,

[3] With *oxalic acid*, a white, heavy, granular precipitate; *all* was precipitated even in a very acid solution.

[4] With *ammonia*, a white, bulky precipitate.

[5] When boiled the solution yielded a granular precipitate, which after cooling was again dissolved.

The two first reactions show that no titanic acid is present, the third that there is no zirconia, and, together with the fifth, that the substance must be thoria.

I have further searched for chlorine and fluorine, which were found not to be present. When determining the water I first dried the mineral over sulphuric acid, after which it lost 0.95 % water at 100°. The remaining water was expelled in a combustion furnace and weighed directly in a tube with calcium chloride, as the loss by heat above had proved to yield too small a figure, on account of the peroxidation of the mineral.

The analysis yielded the following result:—

SiO_2	27·95
TaO_2	0·97
Fe_2O_3	9·71
Al_2O_3	2·41
Th O	7·09
MnO	4·20
Ce O	10·66
La O, Di O	17·04
Ca O	3·09
Na_2O	7·98
H_2O	7·28
	98·38

As the separation of thoria from the oxides of the cerium-group which is effected by sodium sulphates is not exact, and as moreover the composition of the mineral is very intricate, I shall not attempt to deduce any formula, until more analyses have been instituted.—

Prof. *Johnstrup* has kindly communicated to me the following remarks on the occurrence of lievrite and lepidolite in Greenland:—

On examination of the minerals, which in 1874 had been brought home from Tunugdliarfik and Kangerdluarsuk by *Mr. Steenstrup*, I perceived, that besides the arfvedsonite and segirine a third mineral was present, which differed somewhat from

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the others as to crystallization, lustre and specific gravity. An analysis convinced me, that it was *lievrite*. As I have informed you, that this mineral had not previously been found in Greenland, though the contrary has been stated in several works on Mineralogy, I think it necessary to account for this apparent contradiction, even if this rather unessential question should thereby be treated somewhat more at length than I wished to do.

When *Dr. Rink* names lievrite amongst the "doubtful Greenland fossilia,"* it is not without reason; for in the collections of Greenland minerals, which *Giesecke* in the years 1814, 1817, and 1818 sent to the Copenhagen Museums, is only found a single specimen which might contain this mineral. The label says: "Jenait (ought to be Jenit or Yenit) mit Granat, in Granit von Kangerdluluk." Giesecke does not however mention it in his Journal, and therefore cannot have attributed much weight to this occurrence. As probably there have been similar specimens from this locality in the collections which he supplied to the foreign museums, it is easily explained that *Leonhard* in his "Handbuch der Oryktognosie, 1821," amongst the lievrite localities also mentions *North Grsenland (Kangerdluluk, mit Granaten in Granit?)* whence it was adopted in his son's "Handwörterbuch der topographischen Mineralogie."

To Leonhard the correctness of this statement may have seemed doubtful, which the sign of interrogation sufficiently shows, and an examination which I undertook of the specimen named, also proved it only to contain amphibole, not lievrite. As upon the whole he deposited the finest specimens in the Copenhagen Museums, there can hardly be finer ones abroad. Therefore the lievrite ought not to be considered as a Greenland mineral till 1874, as till then there had never been pointed out any other occurrence than that above mentioned.

When *Des Cloiseaux* in his Manuel de Minéralogie (1862) in the section "Ilvaite" does not mention *Kangerluluk* (North Greenland) but *Kangerdluarsuk* (South Greenland), he has probably been mistaken about these two localities, the latter being better known on account of its rare minerals. Hence also *Dana* may have adopted this occurrence in the fifth edition of his Mineralogy (1868), while it is not mentioned in the fourth edition (1854). It is then a remarkable case, that the first locality where the lievrite really has been found in Greenland, is the same, which has been given by mistake, while the locality originally stated, viz: Kangerdluluk in North Greenland, should now disappear from the catalogues.

With regard to the *lepidolite*, which in your paper is stated to be new for Greenland, it ought to be remarked that *Giesecke* in his journal† says, that he found it in the immediate neighbourhood of Julianehaab, but, as I have remarked in a note, from this locality it is not found either in the Copenhagen or the Dublin collections. A lepidolite from Kangerdluarsuk he does not at all mention, although it is found in small quantities on the sodalite-syenite brought home by himself. Probably he has thought it to be a common potassium-mica.

* *Rink*: Groenland geographisk og statistisk beskrevet. Tilleg, p. 152.

† *Giesecke*: Mineralogiak Rejse i Groenland. Kjoebenhavn, 1878, p. 16.

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The Geognosy and Mineralogy of Scotland.

By Professor Heddle.

SUTHERLAND.—Continued.

The Upper Gneiss.

While agreeing with those writers who affirm that many of the members of this series are of the nature of schists,—sometimes almost flaggy schists, still, even when examined throughout their multitudinous varieties, it has to be affirmed that they are all *gneissic* schists; and, however fissile some of these members may be, this is far from a sufficient reason for attempting to dispense with a time-honoured appellation;—one moreover which is more fittingly applied to them, than to the somewhat *more generally hornblendic* rock to which alone it has been proposed to confine its use.

As perfect a gneissic structure, nay, even a more perfect gneissic structure is to be seen in the rocks between Tongue and Farr,—in Strath Oikel, or at Strath Virick, as in any part of the "hornblendic gneiss"; and the gradual transition of such rocks (generally as we ascend on the series,) into readily cleavable flat flags,—whether gritty, micaceous, or aluminous,—shews the latter to be but lithological allomorphs.

Changes quite as marked, both as regards proportional increase of one or other ingredient, and as regards structural modifications, are found to obtain in this upper system of rocks, when we track them *along their strike*;—even when we are kept rigidly thereto by restricting ourselves to an examination of that basement layer which is in contact with, or immediately succeeds to the upper quartzite.

Sooth to say, it becomes very much of an enigma, if we suppose that layer to have been deposited upon anything approaching to a level ocean-floor, how rocks so very dissimilar as those which we find in different districts along this line, can have been simultaneously laid down.

Over the quartzite at Whiten Head, may be seen at the Bodach-Derg, a dark-green rock, coarse in structure, and largely formed of what

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was possibly hornblendic mud. This rock is generally so similar to parts,—especially to decomposed parts of the hornblendic gneiss, that it is not altogether to be wondered at that they were at one time considered to be the same.

This Whiten Head rock has by one observer been called "chloritic schist."

While it is *chloritic* in the sense of being *green*, it certainly is very different from the true chlorite-slate of Ben Lomond, and the south-west of Scotland. The colouring ingredient seems to be a mixture of pounded hornblende with minute scales of muscovite. Very possibly it is a repetition in force, of the schistose green beds which at many points underlie the Logan rock.

As we pass southwards we come, in the neighbourhood of Hope Lodge, to beds of a quartzose character. These, considered along with others which lie between the Hope Ferry and the limestone of Heilim, may be taken as supplying fair ground for holding *that the quartzite there passes upward by a system of separated beds into the upper gneiss;* and as entitling us to refer both to the same epoch.

The uppermost of these beds lies about a fourth of a mile to the east of the Lodge, and it differs markedly from the rock last noticed. It might, from its extremely schistose character, be termed *paper-quartz*. Its appearance, which is somewhat that of a mica-schist deprived of its mica, conveys the impression that it is an example of pseudomorphism in a rock mass.

Still further southward, an increase in the quantity of mica beyond that of the Bodach-Derg Rock, gives us the "Oyster Shell Rock" of Craig Vercan. This larger amount of mica is here asserting itself in the attempt to form crystals; but the associated hornblendic mud, may, by distorting these, have produced the curvilinear "oyster-shell" structure.

Still further south, the total removal of the dark-coloured ingredient gives us, at Leiter Mussel, a mica-slate, which cleaves into plates as thin as a writing slate. In the Loch More and Loch Merkland district, it has become a clay-slate, dark in colour, merely glistening with mica;—not far from the *phyllade* of the French.

On the eastern side or end of the ridge of Ben More, there is so small an amount of the sand-grains that the rock, when wet, works into a plastic clay. East of Loch Ailsh, the silica has returned in such quantity and with so much coherence, that some would term the flags quartzite.

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On the road between Knockan and Ullapool, it looks like a clay-slate, with some bands largely made out of a mud of comminuted hornblende: while, south of Loch Broom, down to Fionn Bheinn (Ben Fin), and away to the south-west, the mica in predominating amount has again come back in glittering scales of yellowish muscovite, studded with garnets and interlaminated with quartz;—the veriest gneiss of all the range.

The line is a fairly straight one now, with no great amount of vertical undulation; but when it formed the sea-bottom, it may have lain in wrinkles: and at present we can only speculate as to how much of this local segregation of these dissimilar materials may have been due to substances of higher gravity settling first in the deeper pools;—and how much to slight differences or intensities of a local metamorphism, which produced different results from elements occasionally differing but little, if at all.

The marked dissimilarity of the rocks which immediately overlie the quartzite in Sutherland proves that, in attempting correlations in a country, it will not suffice to make an eight or ten mile section across a series of rocks;—a traverse of a hundred miles, keeping faithfully to the strike or along the junction, is also imperatively called for.

Although neither typical chlorite-slate, mica-slate, nor clay-slate, occurs among these rocks, the marked difference in their structure and composition, shews the wide range in lithological character and in mineral composition, which may occur in the members of one formation; and also testifies to the impropriety of any attempt to set aside a long-established name upon the merely-local features of one of its members. The proposal to dispense with the term "gneiss" as applied generally to the members of this formation, is therefore, on every ground of scientific nomenclature, to be deprecated. It was *to this very class of rocks* that the term was first applied in Scotland, and has ever been applied; we may indeed doubt if those who introduced it ever saw saw that "Hebridian gneiss" to which it is now proposed to restrict its use. Should the progress of discovery necessitate a distinctive term, such term must be applied to the rock which, in virtue of its dissimilarity to the recognised type, calls for an extended nomenclature; and the confusion which could not but have ensued from the adoption of any other principle in the present case (and which in point of fact has ensued) quite called for Nicol's remonstrance, that "it would take more arguments than had been brought forward, before he

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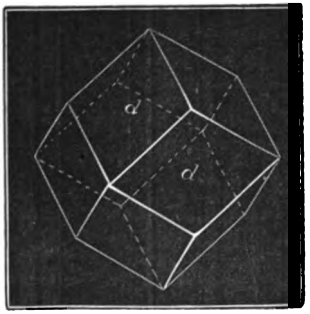
could be induced to believe that Jameson and Macculloch, Boué, and Necker, did not know gneiss when they saw it." *

Minerals.

These occur not only in much greater numbers and variety, but are markedly different in what may be termed *type*, from such as I have above recorded as having been found in the hornblendic gneiss.

From the very varying basement layer of the upper gneiss, I procured minerals in but one spot. This was from the mica-slate. The locality was the foot of a line of cliff called Leiter Mussel; this is a south spur of Ben Hope.



At the north end of this cliff we (D. & H.) got garnets in rhombic dodecahedral crystals; these were sometimes formed of successive layers of garnet, with bands of grains of silica,—in fact glistening sand. These bands though composed of a mechanical debris, had been so under the control of the accession of each new layer of garnet, as to have been caught up or pushed before it, whilst the material of that layer was being drawn to the common centre of the crystalline action.

* That no very marked petrological distinction can be drawn between the two classes of rocks, may be shown by quoting from the writer who most urgently insisted upon the change of name.

Sir R. Murchison in 1858, writes—"we ascertained that Farrid Head consists of the old gneiss." In 1859, he writes "that promontory was erroneously referred to the old gneiss in my former memoirs, on conclusions drawn from a hasty visit of my friend Mr. Peach, who brought me specimens from one part of the headland, which had a gneissose aspect."

One of two conclusions must be drawn from this—either, that the *haste* lay most in the writer's inferences,—or, that these specimens so strongly resembled the old gneiss, that the very geologist who was desirous of separating them, was himself unable to distinguish between them.

And yet, writing in 1861 we find Murchison again saying—"we are of opinion that no geologist can confound the fundamental gneiss with the so-called gneiss of the superior crystalline schists, which, instead of being a massive hornblendic and granitic rock, is a flag-like, micaceous, and quartzose deposit of very different character."

No strata of the upper-series are *more* "flag-like, micaceous, and quartzose" than those of Farrid Head; yet their "great dissimilarity" in character to those of the lower-rock would not appear to be so marked as to be *always* capable of ocular apprehension; and it is therefore strange that they should have formed the text for the above quoted specimen of scientific dogmatism.

The climax as regards the rocks of the Farrid is more curious still. We find in a foot note to the last paper by Murchison (Feb. 6th, 1861), that specimens of the rocks *from this promontory* were exhibited to the meeting "to show their dissimilarity to the old gneiss of Kean na bin, with which Prof. Nicol connects them." Many years ago Dr. Macculloch cynically told us that geologists had "to be taught even to see;"—does not the above entitle us to say, that we should be taught to be *slow to believe*? And what do the words "with which *Prof. Nicol* connects them" teach us,—seeing that Murchison was himself the first to make the connection?

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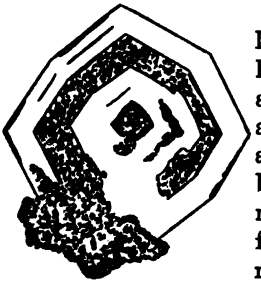

The crystal figured *seems* to have a crystalline nucleus of granular silica:—it can hardly be conceived that the centripetal action of crystallizing molecules could induce a powder, caught up in their midst, so to arrange itself as to assume a form not belonging to the system in which its own material usually crystallised. Probably therefore there is in the specimen a minute nucleus of garnet.

This garnet has a specific gravity of 4·127.

It yielded—

Silica	35·
Alumina..	21·539
Ferric Oxide..	2·822
Ferrous Oxide	26·537
Manganous Oxide	4·461
Lime	7·107
Magnesia	2·307
Water	·143
	99·916 (H).

The rock which contained these garnets was very peculiar. *Actinolitic hornblende* of a fine colour was present in lanceolate crystals; the matrix was a snow-white granular silica of extremely high lustre,—each grain sparkling, transparent, and appearing as if quite detached from those in contact with it.

Midway between this locality and the waterfall on the Allt na Callich, crystals of *hornblende* lie sprinkled like grains of corn, in a similar matrix. Both varieties form specimens of great beauty.

Actinolite-slate occurs at both localities, in small quantity.

Inferior specimens of *chlorite* with *magnetite* occur upon the south slopes of Ben Hope.

The discovery of mineral localities in the upper-gneiss of this county must be to a large extent fortuitous:—from its vast extent it would be impossible for a single explorer thoroughly to examine it.

Dr. Joass, observing a singularly elevated ridge in the neighbourhood of Collabol, searched it, with the result of finding lamellar *baryte*, coated with *chrysocolla*.

A little to the north-west of this, a very peculiar and beautiful hornblendic-rock occurs (D. and H.).

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It appears to consist of nothing but a fine granular felspar of a cream colour, containing imbedded patches of light-green fibrous *hornblende*.

Small crystals of brilliant *epidote* occur in its cavities, and also, rarely, minute *sphenes*.

A well-marked hornblendic rock with a granular felspar, occurs also at the knoll called Cnoc na haire, some miles to the west;—also near Overscaig,—the whole of this district, indeed, being markedly hornblendic.

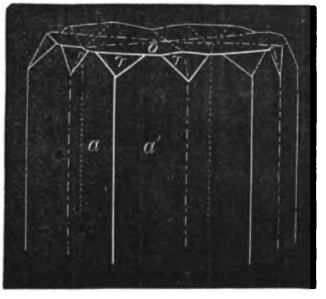
Achadhaphris.—This is the name of a farm which lies about a mile north of Loch Shin and a little east of Collibol. During the improvements carried out by His Grace the Duke of Sutherland, the ground was here much cut into; and during the ditching the rock was in one or two spots exposed.

It was found to be a hornblendic gneiss, with a north east dip.

The *hornblende* was somewhat foliaceous, and light in colour.

The small amount of the rock which was exposed yielded, in its more felspathic portions, the following minerals.

Sphene, (D. and H.) Ill-defined and small crystals of the short flat form which is common in Scotland, occur in the more felspathic portions of the rock; they are of a pale hair-brown colour.



Apatite (D. and H). Occurs in small pale bluish-green crystals, sometimes in twinned forms as in the figure. It accompanies the sphene. Both of these minerals have here somewhat of a waxy lustre.

Minute fibres of *rutile* were associated with the apatite.

Lepidomelane (D., Jo., and H.).—This mineral, so rare in Scotland, occurs here in plates of two to three inches in length. The colour of these plates was from a yellowish-brown to a chocolate-brown. They were easily cleavable; but, as the mineral was brittle, only short flakes could be raised. It was slightly bi-axial, and had a muddy yellow-brown colour by transmitted light. The specific gravity is 2·971.

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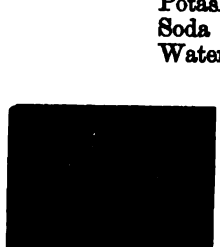
Its analysis yielded—

Silica	40·384
Alumina..	12·11
Ferric Oxide..	14·523
Ferrous Oxide	3·03
Manganous Oxide	3·146
Lime	1·033
Magnesia	13·
Potash	7·128
Soda	1·801
Water	3·567
	99·722 (H).



Ilmenite in thin plates was associated with the lepidomelane (D. and H).

There was found here in making the clearances, a piece of white quartz studded with small but finely formed crystals of *rutile*. Some of these crystals were in the form of the annexed figure. This was the most perfectly crystallised rutile which the writer has seen from Scotland.

Clach an Eoin.—The tract of country which lies on each side of the river Naver, and indeed the whole whole way between it and the Borgie is of extreme roughness. The gneiss seems tumbled in all directions, and is removed not only from its normal dip, but presents characters of a higher metamorphism than it displays in most parts of the county.

The rock or craggy knoll called the Clach an Eoin exhibits on its glaciated front a peculiarity of structure which I have not seen described. In comparatively feeble development something of the same kind is to be seen in the gneiss of Boggierow quarry, near Portsoy,—at Strath Virick bridge near Arguish,—and at Innisbay, on the Dirrymore road.

At the first, and possibly also at the second of these localities, the structure may be regarded as a mere modification, or a badly developed instance of porphyritic arrangement in the felspathic portion of the stone.

At Boggierow the crystals of the felspar, if felspar they be, are devoid of all edges and angles, appearing rather as kernels or nodules, of some half-inch or so in size. Of these there is here no definite arrangement whatever,—they are promiscuously scattered throughout the mass.

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As regards the size, and want of angularity of the felspathic portions of the Innisbae rock the above also holds: but there is here no promiscuous scattering,—no absence of arrangement: these felspathic kernels lie in regular layers which accord with the micaceous lamination of the rock,—following obediently that lamination where it has been crumpled. Something very close to this is given by Cotta, as his description of typical porphyritic gneiss:—"in the otherwise uniform schistose mass there occur at intervals, large egg-shaped crystals of orthoclase (sometimes amorphous), round which the foliated texture bends itself with a wavy sweep." This description approaches it, though it is really different from, what is to be seen at Clach-an-Eoin.

The study of the Boggierow rock leaves the impression that the felspathic portion had attempted to arrange itself as crystals, or had been crystals,—porphyritically disposed. Such a conclusion will hardly apply to the Innisbae rock,—the felspathic matter is certainly not porphyritically disposed when it is confined to a regular arrangement in layers; and such a conclusion certainly will not apply at all to what obtains at the northern locality. First, it will not apply in *size*;—the individual collections of felspathic matter, to which inches would apply at the other localities, are here of the dimensions of feet and yards. Second, it will not apply as to *internal structure*; a certain amount of rough cleavage which is to be obtained in the first cases, showed that each—all being much of a size—was to be regarded as an individual mass of which the components were *its molecules*; here, nothing like cleavage is to be got; the components are crystals, granules, plates, promiscuously agglutinated, and forming masses of greatly varying size. Thirdly, it cannot apply as to *shape*; there is here no residual trace of geometric form,—for the masses are lenticular.

The strike of the rock is N. by E. and S. by W.; it stands nearly vertical; its bedding is well shown by the parallel disposition of its layers of black mica; it is singularly free from all plication; between the bedding of its micaceous layers, however, there occur in marked abundance, though at quite irregular distances, parallel arrangements of the segregated felspar of the rock, disposed like the glands on a duct, or ganglia on a nerve,—the enlargements being of ever varying size, composed each of numberless crude crystals, and hence totally different from *Augen-gneiss*.

In one respect the comparison with ganglia on a nerve is not satisfactory—the felspathic bands are generally not continuous; but the juxtaposition of the two micaceous layers which lately sheathed what I have represented under the figure of ganglionic enlargements, leads, in straight course, to the next and not far separated lenticular mass.

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There can be little room for doubt that this is a modified development of that segregatory process in virtue of which the felspathic material of gneissose rocks so frequently arranges itself in layers or belts. As these belts consist of a material more plastic when heated than the less fusible quartz and mica, they are, where plicated, thinned off to nothing at the more compressed flexures, only to re-appear in ampler development among the loosened or more drooping folds. But at Clach-an-Eoin we have no plications which compress or loosen,—*the portions of the rock where the felspar thins off, being actually the least compressed of the whole;—this is seen by the opening out of the micaceous layers in the immediate vicinity.*

Can it be that metamorphism—for it is a district of considerable, though not extreme, metamorphism—has rendered the more fusible material so plastic, that cohesion has here been tugging hard to cause it to assume actually a spherical form, and has been baffled only by gravitation, which flattened out the sphere into a lens-like shape, or rather retained what, without its action, would have been a sphere, in a lens-like shape.

But the description is as yet faulty: I have used the recognised geological term "lenticular" as the adjective altogether most applicable; but the relative proportions of these masses—which vary from the size of a goose's egg to that of a grampus,—are a length about twice as great as their breadth. Since, however, they thinned away also somewhat as they merged into their connecting band, they presented an appearance so similar to that of an *eye*, that it appeared to my fellow workers, Dr. Joass and Mr. Dudgeon, that it would be most fitting that we should meanwhile designate what I have described, as an "oculitic structure."

The black mica, which so clearly defines the rock-layers, is here *Haughtonite* (D. and H.)

Towards the north-east cliff of the hill, it is to be found in plates of some inches in size; these plates protrude edgeways from the quartz-veins of the rock,—are much weather-worn,—and have upon these weathered edges the colour and lustre of somewhat tarnished metallic lead. This weather-wearing affects only the edges of the crystals, which have smooth rounded depressions with an appearance as if portions had been eaten out by some insect. There is not the smallest appearance of internal alteration or even of loosening asunder of the plates, as in the case with the mineral from Cape Wrath. These plates are associated with *garnet*, *rutile*, *ilmenite*, and *chlorite* (D., Jo., and H.). All are imbedded in quartz.

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The colour of the Haughtonite is clove-brown; red-brown by transmitted light. The plates are uniaxial, or very slightly biaxial. The specific gravity is 2·96.

It yielded

Silica	35·846
Alumina	21·539
Ferric Oxide	4·467
Ferrous Oxide	18·306
Manganous Oxide	·307
Lime	1·249
Magnesia	8·076
Potash	7·759
Soda	·794
Water	1·956
	100·299 (H.)

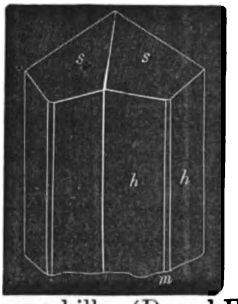
The *garnets* here occurring are quite inferior in quality and form,—they are rhombic dodecahedra of a brown-red colour.

They yielded—

Silica	39·923
Alumina	19·808
Ferric Oxide	13·69
Ferrous Oxide	13·294
Manganous Oxide	1·
Lime	9·132
Magnesia	3·307
	100·154 (H.)

When the nature of the matrix is considered, the quantity of lime is great. The *ilmenite* is in blue-black plates, and is rare; the *chlorite* is in small ill-defined rosettes of crystals.

These are all associated with the Haughtonite; on the north-east side of the hill.



The rutile occurs in single, isolated crystals, imbedded in a yellowish vein-quartz, upon the top of the Clach. The crystals are small but fairly well formed, as in the figure. Some are translucent and ruby red.

Rutile in crystals nearly two inches in length, but transversely fissured, with the matrix lodged in the interstices, occurs also in a yellow quartz, in the crags beneath a Pictish "brough," which is placed upon the south-east shoulder of the same hill. (D. and H.) The form is indistinct.

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I have received through Dr. Joass portions of a rock or stone,—I believe a large boulder,—which was found in making a road at Ribigill near Tongue.

This consists of a basis of fine-grained, scaly, and very soft chlorite, (apparently); in this there are disposed in a porphyritic manner, at distances of about an inch, crystals of lustrous white *talc*, of about the size of peas.

In my experience the rock is unique. I have some hesitation in calling the one mineral chlorite, on account of its extreme softness, and from its being weathered to the depth of an inch. This is a greater amount of change than I ever saw in chlorite: it bears some resemblance to scaly saponite; but the occurrence of talc in association with saponite is unknown; as is the occurrence of saponite in sedimentary rocks. From "till," a little south-east of Tongue, I have myself got ordinary unchanged chlorite, imbedded in white quartz.

The Primary Crystalline Limestones.

These are known in Sutherland in but two localities,—the north and the south shores of Loch Shin;—at Shinness, and at Arskaig.

At these localities they present the appearance which is so usual to this rock in its higher state of metamorphism,—a congeries of crystalline particles which have mutually nullified each other's efforts to assume a regular form, and so have produced only a granular mass,—the cleavages of the several granules lying in every direction.

The primary limestones of Scotland sometimes present themselves as extremely barren of minerals; at other localities they contain a few species, which may be said to pertain to such limestones in a very special manner; while again they occasionally supply so many mineral species as to present themselves as one of the richest matrices of all rock masses. It thus becomes of interest to examine into the circumstances, and to endeavour to attain to the causes of this diversity of fruitfulness in limestones.

The first fact which is noted after the enquiry has been sufficiently extended, is that the *nature of the rock* immediately in contact with the limestone seems to have little influence; and that regard has to be had, primarily, to *the physical circumstances in which the lime is placed.*

It will be observed, that if the limestone bed is *of trifling dimensions* it will afford no minerals,—whether it be disturbed or undisturbed, convoluted or not so.

Turning the attention to the conditions and characters of the lime rock itself, it will be found that in this case it is simply *limestone*, (generally

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dolomitic),—a more or less impalpable paste, amorphous in its nature, structureless, and more or less coloured or muddy, evidently through mechanical contamination.

If we look next at the including rock, it will be found that it shows no changed structure,—no greater amount of metamorphism in the vicinity of the limestone, than throughout its general mass.

It will also be observed that not only does the limestone contain no minerals, but that the strata in contact with it also afford none other than those which go to form its general mass; and that under such circumstances the crystal-dimensions of such constituent minerals is not increased.

All this *also holds*, with equal force, under the circumstances of the lime-stratum being of considerable thickness, so long as it is untroubled or convoluted.

But it is not so if the stratum be, at one and the same time, large in mass, and either itself highly-contorted, or, in those cases where it is not sufficiently exposed for this to be determined, if it be seen to be lying among highly-contorted rocks. Then, the calcareous mass no longer is amorphous in its substance; it presents itself as a *granular limestone*, often as a true marble; that is, it is *calcite*, and is crystalline in structure, and in all its inherent properties.

Here the including rock in the immediate vicinity, is much more highly metamorphosed than it is throughout its general mass; the crystalline development of its constituent minerals being not only more distinct, but more ample.

While lastly, imbedded in the limestone, and to a smaller extent in the altered rock, but in both cases near their point of contact, there are found numerous minerals which *are such as can be formed by the union of the constituents of the inclosed limestone with the inclosing rock.*

These three circumstances, then, I believe to be invariably observable with regard to the "primary limestones,"—namely, that whenever they are much folded or crumpled,—thrown at a high angle,—or when the adjoining rocks exhibit rents and fissures,—there the granular structure will show itself in the largest development of individual particles;—there simple minerals will be found in immediate association in the greatest numbers and amount;—and there the limestone will be the purest *in its own substance*, as regards both colour and translucency.

This directly points to *combination having taken place between the constituents of the rock and of the limestone*; and, if the amount of such combination be at all in the ratio of the amount of folding and contortion, it may result that the whole amount of the calcareous

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matter has been taken up in such combination,—and *the limestone stratum, as such, may actually disappear*.

Local interruptions in the continuity of a limestone stratum, while a continuation of a vivid grassy verdure vouches, in these, for the presence of a large amount of calcareous matter in the rock which yields the soil, are of frequent occurrence in the Highlands.

In the bed of limestone which courses down Strath Dee, a gradual increase of the amount of imbedded mineral, (here malacolite,) and diminution of residual calcite, may be traced as we follow the bed through the constantly augmented plications to which it is subjected as it passes eastward. An average sample of the limestone taken from the Glengairn quarry, leaves after treatment in acid, about 3 p.c. of insoluble mineral. The percentage of residue increases as the stratum passes eastward along the course of the Dee. In the stone from the quarries which are opened into it as it twists about at Muir and Midstrath, there is so little calcareous carbonate that a fragment retains its shape after treatment with acid; while Dr. Young tells me that the substance which was worked and burned as lime on his property of Durris, *does not effervesce at all*, when so treated.

The most striking feature, however, is the change effected upon the rocks which are in contact with the limestone. So marked is this feature that, under the circumstances detailed, these limestones may be said *to function* in the Highlands *in a manner somewhat similar to that of igneous rocks*;—I mean as regards the changes which they seem to induce.

Such a mode of functioning is most anomalous, at first sight, as regards a substance and a structure unquestionably of organic origin; it is only to be explained through a consideration of the *circumstances* which obtain, and cannot well be assigned to the *mere presence* of limestone in a rock which is undergoing ordinary metamorphism.

Ordinary metamorphic change is, in our almost total ignorance of the subject, usually assigned to a hydro-thermal action, which has taken place at great depths, i.e., under enormous pressure. Such a thermal change should affect a plicated, and a nonplicated included rock alike; and should certainly affect a thin bed of limestone more than a thick one. As the result of any change thus pressing from *without inwards*,—that is, from the gneiss to the limestone,—we should expect to find the thinner parts of the stratum of the latter wholly converted into large granular marble, and very fully pervaded with mineral species; while the thicker parts of the limestone should be much less altered in both respects; but this is the opposite of what

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obtains; and so any explanation which requires that the agent of change should act from *without inwards*, does not suffice.

The whole facts of the case seem to point to an action taking place from *within outwards*. This view, at least, would seem to account for there being a greater change where the stratum is thickest;—the greater the mass, the greater must be the amount of action, if that action proceed from within.

But what action, physical or chemical, can be conceived to take place within, or emanate from a sedimented, amorphous, organic limestone, which could credit it with being at one and the same time the agent of its own metamorphosis into its crystalline allomorph,—of augmenting the metamorphosis of a rock in its immediate neighbourhood,—and of stimulating to the chemical union of the material of its own mass with the constituents of that rock?

Among the physical agencies which induce a change from the amorphous or colloidal to the structural or crystalloidal condition, we find *plication* and *heat*. Sir James Hall's experiments have shown that direct heat under pressure will change limestone into marble or calcite; and *plication*, in the very act of transforming a colloid into a crystalloid, does so at the cost, so to speak, of an elimination of heat from the substance so plicated. If we melt lead and pour it out on a flat stone, it assumes upon cooling the structureless, amorphous form, with rounded colloidal outline. If, after cooling, it is bent in the hand, it gives out heat, becomes crystalline in structure, gradually loses its pliability, and assumes the brittleness inseparable from the crystalloidal state. The same holds for iron, and for all metals capable of assuming the colloidal state; bend or beat them, they give out heat, becoming crystalline and brittle in so doing.

The heat here eliminated is doubtless partially the representative of arrested motion; but it is probably *chiefly* an outcome of the change from the colloidal to the crystalloidal condition; the agent of the elimination was the plication to which the substance was subjected, which plication was at the same time the immediate agent of the physical transformation.

I would venture to predict that it will come to be found that *the specific heat of substances in their colloidal state is always greater than that of their crystalloidal.*

I am not aware that any researches have been made specially to determine this point; or even that the attention of physicists has been directed to it; but the following table, which embodies all that I have been able to find, seems clearly to bear out such a view:—

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COLLOID.		CRYSTALLOID.	
Water	1·	Ice	·72
Lamp Black	·26	Graphite	·201
		Diamond	·174
Limestone and Chalk	·264	Calcite and Marble	·201
Chalcedony	·195	Quartz	·179
Titanic Acid (artificial)	·172	Rutile	·163
Peroxide of Iron (artificial)	·176	Hematite	·166

Should it prove to be the case that the amorphous form has a specific heat always exceeding that of the crystalline, a step probably will be gained in the explanation of metamorphism generally; it may at least be held that the high specific heat of limestone, and the much lower heat of calcite or granular marble, explains the local metamorphism which we are now considering; as the plication, crushing, and folding of the strata *expressed, or extricated as heat of active energy* the difference in the amount of the specific heats of carbonate of lime in its two states,—the excess which is special to it in the colloidal. This expressed heat left only a residue, so to speak, sufficient for granular limestone; while it became the active agent in stimulating the chemical affinities existing between the limestone and the silica, alumina, and alkalies, of the gneissose matrix. It thus led directly to the formation of minerals, while it at the same time expedited or perfected a more thorough metamorphosis,—i.e., the assumption of a more perfectly-developed crystalline structure, in the previously only partially metamorphosed rock.

The assumption of a definite crystalline structure,—a character or property directly attached to a definite chemical composition,—must of necessity extrude from the resultant calcite the phosphate of lime, and fluoride of calcium, which limestones contain uniformly distributed throughout their mass. *Apatite* and *Fluorspar* are accordingly among the crystallized minerals found imbedded in the saccharoid "primary" limestones.

Whether the extruded heat can actually *fuse* the residual calcite may possibly yet be ascertained by direct experiment; but it would seem to be almost a necessary deduction that no mineral could be formed by such an action possessed of, or requiring a specific heat greater than that of the original source of the expressed heat.

It must be borne in mind that chemical elements do not alone go to the formation of any substance;—a due amount of certain physical agencies is the special portion of each, lodging, as it were, in their pores as resting places. Of the chemical ingredients, one alone may suffice; of the physical agencies, among which heat, phosphorescence, and magnetism, may be said to be those most germane to minerals,—

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heat is the only one which is never absent. Chemical affinity then can only *predispose* to the union of the constituents which go to form the substance, for something more is requisite before the formation can be accomplished,—before the substance can, so to speak, assume an independent existence,—namely, the supply of the heat special to it,—to the perfect putting together of the whole as a mineral species.

It has, however, to be admitted that we are unable positively to affirm that the expressed heat may not be so concentrated in the spots where the chemical action is operating, as to afford any specific heat required.

Two arguments against such a view may, however, be adduced.

The first.—That the heat extricated throughout the general mass, would not readily be localised, or carried specially to any point in so badly conducting a substance as granular limestone or marble; more probably would it accumulate within the limestone itself, even to the point of its fusion;—and indeed the occurrence of porphyritically disposed crystals of quartz, with rounded angles, throughout the general mass of some marbles, (e.g. Ledbeg, Sutherland,) would seem to indicate actual fusion.

The second.—That it has not yet been shown that there is the necessity for such concentration.

The high specific heat of the matrix is, in the present case at least, amply sufficient; no one of the minerals found in the above localities possessing so large an amount of heat as ·264,—that of limestone.

That of the following is known:—

Fluor	·19
Apatite	·17
Tetrahedrite	·192
Actinolite	·204
Augite	·195
Diopside	·19
Pyrrhotite	·16
Molybdenite	·102

It is a somewhat significant fact that *limestone has a specific heat superior to that of any other rock mass;* we speak of mollusks and crustaceans as "cold blooded,"—though it is believed that they have a temperature somewhat higher than that of the medium in which they live;—but the calcareous matter which they have secreted from solution in that medium, for the defence of their soft parts, is deposited and arranged with an organic and non-crystalline structure, and consequently has had conferred upon it the high specific heat of the amorphous state; and so the long buried skeletons of these

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organisms are abiding store-houses of heat, until called upon to yield up their surplus store, and thus become the active agents of future change.

I have here, as an indirect corroboration of certain of my views, to direct marked attention to the following observations on the circumstances which were conceived by the writers to be capable of accounting for the markedly crystalline texture and high metamorphism of the rock which occurs in Glen Logan in Rosshire.*

Mr. Hudleston speaks of "the complex dislocations of the region."

Nicol says that the rock "becomes serpentinous *where in contact with the limestone.*" Elsewhere he writes—"all along this line the rocks are broken by faults—some longitudinal, some transverse—with large fragments, which have slipped down into the yawning chasms that opened into the vast rock, rent asunder as it rose. But there is no reason to regard this as the result of a solitary convulsion. Rather as nature's analogy would teach, that the arch was often forced up and fractured,—often gave way, sank down and became welded anew by intense heat. For long ages the Titanic conflict may have gone on. Is it then wonderful that along this line the strata should be *crushed, contorted*, thrown into apparently discordant position. That masses of one age should be brought into contact with masses of another: that wedges of the higher limestone, or quartzite, should lie alongside or even lower down than the once deeper-seated sandstones or gneiss."

Professor Geikie writes—* * *"seem to us to prove it to be in reality a highly metamorphous band of felspathic grit,—*the superior degree of metamorphism being due to the existence of the limestone*, and possibly also to the larger amount of felspar in the original rock."

Also—"the metamorphism *which is often most intense in the presence of a limestone* is conspicuous here."

Mr. Hudleston writes that it "gives the idea of an old gneiss *partly invaded by extravasated matter*."

Professor Bonney speaks of a rock "which exhibits *a very marked fragmental structure*, which he strongly suspected to be due to *crushing in situ*. That not only the rock itself, but the *limestone* in contact with it appeared to be crushed.

Here it will be remarked that all the observers have noticed,—first, a very unusual amount of crushing and fracturing,—second, an undue amount of a change rarely referred in great part to increase of temperature. This change has by each and all been assigned

* The italics throughout are the present writer's.

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to the presence of. limestone,—while one, apparently from his finding that the felspar of the rock contains lime, says that it gives the idea of being partly *invaded* by extravasated matter.

No one of these writers has, however, attempted to account either for this evolution of an excess of heat, or shown how the presence of limestone came to affect the rock,—or how the rock came to be affected by the excess of heat, in presence of the limestone.

According to the view of the writer, during this crushing and rending, the organic and colloidal limestone, if it became crystalline, must have given out much extra heat;—and in those localities where the greatest amount of this crushing turmoil was going on, the limestone might even come to play its usual part of acting as a flux,—rendering some portions of the rock so pasty, that they were forced into the gaping rents;—"invading" and altering the felspar of other portions; and being in some localities, itself so totally absorbed through combination, that occasionally,—as it is put by Murchison,—the absorbing rock "occupies the place of the limestone."

If the above be a philosophic rendering, then, inasmuch as it has lately been seen to be necessary to discriminate between *injected* rocks, and *eruptive* rocks, so now will it be necessary to find a place, and furnish a name, for those which, in the presence of limestone, have been rendered pasty, or perchance semifluid, by crushing *in situ*.

I shall have to adduce, in future numbers, many localities where the more correctly termed "diallagic rocks" of Scotland, generally if not always associated with limestone,—show themselves to have been originally sedimentary deposits, which have been metamorphosed *in situ*, and that to such an extent that they were certainly softened in their own mass,—assuming *then* that structure which has led to their having been regarded as injected,—sometimes either involving fragments of other rocks, or apparently throwing out "veins."

It was with feelings of no ordinary gratification that I have lately read a paper by Dana, published in the American Journal of Science, for September, 1880, upon "The geological relation of the limestone beds of West Chester Co., New York,"

It is now five years since, in an address, delivered to the Mineralogical Society, in Glasgow, I endeavoured to show how a rock might be rendered plastic if not even fused *in situ* by the heat eliminated during its folding and crushing. Without assigning any of the heat so evolved to precisely the same cause as I did, Professor Dana clearly shows that a certain class of rocks, of diallagic, hypersthenic, and dioritic type, have been so metamorphosed *in situ* through crushing and folding, that they have become fluent to the extent of *involving portions of other rocks* in their mass, and of having been *forced into the fissures* of these rocks.

So important are the views and illustrations of this eminent geologist, and so immediately applicable to the circumstances of many of the diallage and limestone localities in Scotland, that no apology is needed in quoting what follows.

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"The examples of what appear to be veins or dikes are also numerous. * * *

Some, if not all, of such veins must, therefore, be true veins or dikes; and are evidence as to the former fused or plastic condition of the material, and its injection into fissures. Veins formed in this way are not veins of infiltration or segregation; that is, they are not due to the filling of fissures by material supplied slowly in solution or vapour; for no difference in coarseness of texture or structure exists between the rock constituting them and that of the massive rock elsewhere; they are just such as have been made by simple injection. There are also peculiarities in the exterior of inclusions, and in the walls of veins or dikes, in some cases, which favour the idea of fusion. And in other cases, the limestone is impregnated with the hornblendic or augitic material in irregular lines or bands. Still more positive evidence, if possible, of fusion are shown at the junction of the schists of Cruger's Point with the soda-granite, where the schist itself bears evidence of partial fusion, and exhibits other contact phenomena.

The proof of the crystallization of the rocks from a more or less perfect state of fusion or plasticity is thus complete. But admitting fusion or a plastic condition, the question still remains:—

Were these once-fused rocks fused approximately *in situ*; that is, where, or near where, they now lie; or were they erupted through fissures from great depths below? that is, using Dr. Hunt's terms, are they *indigenous*, or are they *exotic*?

If they were fused where approximately they now lie, that fusion must have come from accessions of heat, and such accessions may have resulted from the movement and friction connected with an upturning of the rocks; and it may have been one of the results, in that region, of metamorphic action at an epoch of general metamorphism, and if so, at the very time that these rocks became fused or plastic through the process, other rocks of the region, owing to less extreme metamorphic action, or to less fusibility, may have been left with their bedding unobliterated; just as much granite in New England and other countries received its crystalline condition in the same process, and at the same time with the associated schistose rocks,—the gneisses, mica schists, etc. * * *

As has often happened in the case of granitic rocks, and even granular limestone, the fused or plastic material, under the pressure attending the subterranean movement, would have entered and filled all fissures that might have been opened to it, and so have made veins or dikes having the sizes of the fissures, were they large or small, and possessing also a uniformity of grain like that of ordinary erupted rocks.

Again, whatever the process of ejection, fragments, large or small, of any rocks adjoining such fissures might have become included in the fusal or plastic material. In the writer's Manual of Geology (1880), veins of this kind are called *veins of plastic injection*, an abbreviation of the full statement that they were made by the injection of material rendered plastic or fused during a process of metamorphism. * *

The results of fusion of sedimentary beds under metamorphic action may have distinguishing peculiarities. *First*:—

The kinds of rocks so resulting are likely to vary greatly, at comparatively short intervals, because sedimentary beds often vary thus. They should not have that uniformity for scores or hundreds of square miles, which often characterizes ejections that have come up from the regions beneath the supercrust. Sediments, and therefore sedimentary deposits, are liable to frequent and sudden changes as to material, which igneous outflows cannot imitate. *Secondly*: the rocks are likely to have no columnar (basaltic) structure; because the fractures to be filled in such cases are fractures in rocks which are participating in the movement, and which, therefore, are heated rocks, and not cold. * * *

The facts with reference to inclusions, and all contact phenomena bear directly, as will appear, upon the question as to any stratigraphical relation in the Cortland rocks to the limestones; and they are, therefore, here taken from the vicinity of particular limestone areas. * * *

A natural inference from the series of facts presented in this section would be that the heat was a consequence in part, if not chiefly, of the movement and friction attending the flexing; and that consequently there was produced a more and more yielding condition in the material of the schist as the region of complete fusion was approached, and at the junction, perhaps, a fusing and obliteration of portions of some

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layers of the schist; *but are not these flexed portions of beds, fragments that were broken off and carried up by the fused or plastic material as it rose from the depths below?* They lie so conformably to the flexures of the schist as to suggest *a negative reply* to this query. * * *

Since it is obviously impossible that the inclusions taken in and carried up by rock erupted through deep fissures should be beds of schist 100 to 200 feet long, and a series of such beds separated by the fused rock retaining together their parallel position, we have to admit that these indications of bedding are of *unobliterated* bedding. The rest of the upturned strata were fused or at least softened; these portions of beds were not fused, though flexed and variously displaced.

There is reason for the resistance to fusion in the mineral nature of the beds; for quartz, staurolite, fibrolite, magnetite, are infusible minerals; muscovite and biotite are but slightly fusible on thin edges; and orthoclase fuses with great difficulty, much greater than the other felspars, oligoclase, labradorite and albite.

Thus the study of the phenomena of contact becomes in this region a study of "inclusions;" and the larger of the inclusions turn out to be beds of schist, conformable to the schist. We seem to be thus forced to the conclusion that *the soda-granite* and the included *diorite* were once *parts of the same sedimentary strata with the schist*, and that all, with the Cruger limestone, were once a continuous stratified formation; and that the plasticity given to the granite-making or diorite-making portions, because of the heat, occasioned the exceptional geological features of the region. * *

All the material is very pyrrhotitic. * * *

The impregnation of the limestone along the junctions with pyroxenic or hornblendic material, sometimes in minute crystals, looks as if it may have been in part at least a result of mixture attending original deposition. This view is also sustained by the occurrence in the limestone near the schist, 1000 yards from the point, of coarse spots of pyroxene with mica and chlorite rudely in layers, which must be due to the original deposition of impurity, and metamorphic action. * *

The plasticity occasioned in part of the latter, (augitic and hornblendic rock) during the progress of the metamorphism, accounts for all that looks like eruptive phenomena, even to the broken feldspar grains found in a slice of the pyroxenyte of one of the so-called veins. There is nowhere evidence of injection into or through cold rocks. * *

And, among so extensive masses of rocks that *became plastic or fused in the era of upturning*, this abnormal position of included strata is not strange. * * *

This ledge, although made up mainly of massive norite and augite-norite, bears thus positive evidence of its having once had bedding throughout, and affords thereby a demonstration that its noryte is of metamorphic origin, and that the associated beds comprised also the limestone of the region.

The whole facts appear to sustain fully the following conclusions:

(1.) These rocks, although they include soda-granite, norite, augite-norite, diorite, hornblendite, pyroxenite, and chrysolitic kinds, are *not* independent igneous rocks erupted from great deposits. However complete their former state of fusion or plasticity may have been they are *metamorphic* in origin. On the view reached, it follows that the limestones, schists, and other rocks of the Cortland region, originally constituted together one series of horizontal strata. They underwent an upturning through subterranean movements, and in the course of it, they became metamorphosed; part into mica schist and gneiss, part, by loss of bedding, into the massive rocks. The number of these rocks does not imply widely different ingredients in the original strata. For hornblendite and pyroxenite have the same chemical constitution; the chrysolitic rocks contain no ingredient not in them also, and are peculiar mainly in their less proportion of silica. Moreover, the diorite, norite, and augite-norite are like in containing the same bases in nearly the same proportions. The soda-granite differs in chemical constituents only through its mica, which indicates the presence of potash.

The title of this paper might, therefore, well have been:—

Soda-granite, norite, diorite, hornblendite, pyroxenite, and various chrysolitic rocks made through metamorphic agencies in one metamorphic process.

The geologist will nowhere on the continent find a more instructive spot for a day's walk than in the western portion of the Cortland region.

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He may see enough to satisfy himself that, although there has been fusion and some eruption, it was *not* eruption from the earth's deeper recesses, like that which brought up trap (dolerite) through a series of great fissures, for a thousand miles along the eastern Atlantic border, from the Carolinas to Nova Scotia, all of it rock of one kind essentially; but eruption from less depths, not greater than the lower limits of a series of formations that were subjected together to foldings, fractures, and metamorphic change, *and mostly far short of this.*

While the Shinness locality by no means, according to my own observation, affords the best illustrations of the facts upon which the above speculation is founded, still it is one which aids in supplying direct evidence.

It is observable, as we approach the neighbourhood, that the ordinary muscovitic-schists and lepidomelane-gneiss of Achadhaphriz become more and more hornblendic; while a bed of hornblende rock overlies the lime itself. Hence it would appear as if some thinner beds of limestone, or at least more calcareous strata, had supplied the lime of the replacing hornblende.

It is next notable that the rock adjacent to the lime has suffered, a markedly higher metamorphism; for *determinate crystals*, and imbedded groups of crystals of *orthoclase*, *hornblende*, and *lepidomelane*, are to be obtained from it.

A kind of *welding* of the rock with the lime stratum, is next observable; and this is accomplished by the occurrence of a linking zone *which consists of those minerals which are formed* (*or could be formed*) *by the union of the two.* This zone is here the chief site of the mineral species, comparatively few occurring *in the mass* of the lime itself.

If such occurrence,—*i.e.*, central to the lime itself,—depends upon the separatory crystallization of the several chemical ingredients, and the consequent clarification of the calcarious bed, it is evident that a deposit of pure carbonate of lime could yield only *calcite* crystals.

A dolomite would probably yield crystals of *magnesite* and of *pearlspar* in addition thereto: a silicious limestone would, in addition, supply *Wollastonite** and *malacolite*,—according to the amount of silica present; while a fossiliferous limestone should likewise supply *apatite*, *fluorspar*, and, in the *first* stages of its metamorphism, *pyrite*.

An impure or argillaceous limestone would yield *garnet* or *idocrase*, or a *felspar*:—the latter would be less likely to occur in dolomitic limestone, argillaceous varieties of which would contain *magnesian* garnets.

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*Bischof writes:—"The adherents of the plutonic theory regard granular limestone as sedimentary limestone that has been altered by volcanic action; and they would, therefore, suppose Wollastonite to have originated in the same way, more especially as it occurs in the masses erupted by Vesuvius. It is remarkable that Wollastonite occurs only in granular limestone; not in sedimentary limestone, where the conditions for its formation obtain equally." *i.e.*, they obtain equally according to *Neptunian* views.

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Much more information may be expected to be derived from the minerals which occur in the limestone itself, than from the mere contact-products. If, however, the stratum be not a single thick bed, but, is subdivided by laminæ of what had been muddy silts, the amount of information is minimised.

We are in some localities forced to the conclusion that the marble has been *plastic, if not fluent*. At Glengairn in Aberdeenshire, and Allt Gonolan in Invernesshire, it passes round and cements fragments of inclosed rock, not at all after the manner of a breccia cemented by igneously-intruded calcareous matter.* In the latter case, the size of the rudely crystalline calcareous concretions, depends upon the size of the vein or fissure, from either side of which they grow, sometimes in successive bands or layers with varying size of granules. But the granular structure of the marble, at the above localities, passes into the cementing portions *unchanged in size and appearance;* and the plug is of uniform grain throughout.

Another fact which goes a certain length to vouch for much of the heat having emanated *from the limestone*, is the fact of the invariable occurrence of the *augitic* type of mineral within it.† The assumption of, or at least the fact of the occurrence of *hornblende* in the

* I shall afterwards adduce facts which almost incontestably show that many so-called "igneous rocks" in Scotland owed that plasticity which enabled them to be "injected" into fissures of moderate size, to an exalted metamorphism in situ; the *requisite* heat being due to crushing and folding. At present I confine myself to an *augmentation* of that heat, *consequent upon the presence of lime.*

† So great and so *invariable* is the occurrence of one or other form of *augite* in connection with the "primary limestone" throughout the whole of the Highlands of Scotland, that it was with no little wonder that the writer observed the following statement—in a critical review of a work by Messrs. King and Rowney, in which these authors are being taken severely to task for postulating points in dispute. "Augite and hypersthene are placed among mineral species 'common to ordinary metamorphics.' The authors are surely aware that at any rate normal augite cannot be called common in metamorphic rocks." While prepared to admit that the augite present here in the outer-zone of the contact-band, may, if it shews a uralitic structure, possibly result from a transmutation of the adjacent hornblende, yet there are many localities in which such augite is seen, where there is no hornblende in the neighbouring gneiss; while the mode of occurrence and the amount of the sahlite and malacolite in the limestone, is such as to entitle us to say that it becomes the mineral *typical* of *this* metamorphic rock;—while in some localities *it actually forms its mass*, and this it does to such an extent that the quantity of *augite* in one form or another, cannot, in the upper-gneiss of Scotland, be much smaller than that of the *hornblende*.

Very possibly the above writer will hold primary limestone to be not an "ordinary metamorphic"; and, as he seems to regard augite as being typical of rocks which have at least been *subjected* to a high heat, we should expect him to agree more or less with our views relating to this limestone; his adhesion to our views would bring satisfaction, if we did not observe that the microscope seems to be by him regarded as an *instrument of precision*, instead of being at present a mere adjunct—however valuable,—in lithology.

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adjacent strata has been noticed. In what may called the contact-zone this gives place to the augitic type of the mineral; though *there* an actynolitic, or perhaps it should be said a *zoisitic* form of hornblende occasionally occurs: but, as we pass from the outer sides of the zone *sahlite* makes its appearance, while the central parts of the limestone contain *malacolite* alone. Indeed, as has been noted, that mineral frequently occurs in such amount that but little lime remains.

The last fact to be noted is that there has been, in every case where the lime is highly granular, *a strong reducing action* of some kind. Flakes of *graphite* stud these beds, frequently throughout, (a small vein of it was found at Urquhart); and the *pyrite* of the little-altered limestone, *is invariably pyrrhotite in the marbles.*

I am not prepared in the present state of our knowledge to consider how the carbonic acid was reduced to graphite, or whether any residual organic carbon was crystallised into it. The occurrence of the lower sulphuret of iron (*pyrrhotite* is $Fe_7 S_8$,—*pyrite* $Fe S_2$) is not, in the presence of the formation of the graphite, so difficult of explanation. Both Berzelius and Rammelsberg found that $Fe_7 S_8$ was the direct result of the action of heat upon $Fe S_2$. The occurrence of a spring strongly charged with sulphuretted hydrogen, about 200 yards north of the line, also aids in the explanation in this case; for that gas is the product of the action of even weak acids (? carbonic) on pyrite.

The facts, then, which are to be observed regarding the granular limestones are,—a higher degree of metamorphism, as evidenced by a more dominant exercise of the crystalline force in the adjacent strata;—the occurrence of a *contact-zone*, rich in such minerals as would result from the combination of the siliceous rock with the calcareous seam;—the segregation apart in that seam itself of its own specially constituent parts—and the occurrence therein of reduction products.

The circumstances which are favourable to a dominant exercise of the crystalline force, in the direction of forming crystals larger than the normal, have no power to limit it to the direction alone of inducing merely a state of more ample aggregation. Such dominant exercise must also have given rise to that which is self-evidently a preliminary to the formation of more amply developed crystallization,—namely the drawing together,—the local segregation of the material, through the accretion of which such crystals are built up.

From this it results, that there are drawn to the situation where the crystalline action is operating in full force, certain at least of those

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substances which occur throughout the general mass of the siliceous rock in quantities so minute as to be there incapable of recognition, even with the aid of the microscope. These are now presented to us definitely crystallised from a calcareous flux; and convey all the precise information which a special crystalline form affords. This often more than compensates for the minuteness of their bulk.

Such substances are *sphene, zircon, Allanite, and molybdenite.*

The place of the occurrence of these is significant.

A few crystals, say of sphene, are found in small open cavities, some inches distant from the junction of the siliceous rock with the limestone;—a very few imbedded in the rock near these, but these are distorted through surface contact; but by much the largest number line the surface of the rock where it is in contact with the limestone, and are only seen when the latter is dissolved off by acid.

They are then found to have grown out of the rock surface; and those portions which had been imbedded in the limestone are *perfectly formed crystals*, the perfection of the faces being in no way detracted from by the effect of any crystalline effort on the part of the limestone.

How comes it that the crystals which have formed here are as perfect as those which have formed in the *vacuous* cavities;—and why did they form there at all? *Only because there was there as perfect freedom of motion for the molecules to arrange themselves, as there was in the cavities,*—with greater space also for that arrangement. A fluent medium,—a readily displaceable fluid—must have filled both spaces. Air filled the one; it will not be suggested that the limestone was an after injection, therefore the limestone which filled the other *must have been fluent at the time when the sphenes pushed its particles aside in order to assume their own individual form.*

Nay more, it was no mere hasty arrangement of molecules, in some one of the simplest forms of the mineral;—the forms here occurring are the most complex in the country,—several are twins with many faces. There was time, so to speak, for the deliberation of choice, and the exercise of the highest and most intricate whimsicalities of the force of crystallization.*

When we take into consideration the whole of the granular limestones of Scotland, *andesine, Biotite and sphene* are found to be characteristic of the contact-zone;—*malacolite, pyrrhotite,* and *apatite*

* I do not here, for want of sufficient data, enter into a consideration of the *modifications* produced by the presence of certain media,—calcite, however, does not generally induce complex modifications.

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equally so of the limestone itself;—while *orthoclase* and *actynolite* appear in the neighbouring rocks.

The occurrence of minerals at this—one of the richest limestone localities in Scotland—was first noted by Dr. Joass. Through the courteous assistance of His Grace the Duke of Sutherland, Mr. Dudgeon and the writer were enabled to make a thorough examination of it, at the time when it was being worked. The following are the results.

There are two beds of limestone, each about seven feet in thickness; they are first seen upon the shore of the lake, on the west side of the promontory of Shinness; they extend for about 400 yards as limestone; and the calcareous compounds which they form by their union with the gneissic rock, continue for about an equal distance to the eastward, disclosing their presence in a series of green knolls.

The dip of the beds is to the E.N.E., at an angle of about 35°, and this dip is maintained by the overlying rock nearly to Lairg,—where syenite comes in,—and in a northward direction as far at least as to the road which passes to the Crask.

Both beds are similar; being large granular, with at times very little cohesion of the granules. The upper is the coarser in structure, the granules being of the size of peas. This bed is sometimes very strikingly diversified by red bands of a high colour and a parallel disposition.

In its general mass the limestone is very pure, the minerals occurring only towards its sides, and chiefly the upper side. The intermediate zone of rock is about a yard in thickness.

Dr. Thomas Anderson has given the following analyses of the limestone.

	TOP.	MIDDLE.	BOTTOM
Carbonate of Lime	84·11	93·70	89·95
Carbonate of Magnesia ..	7·45	3·49	4·93
Ferric Oxide and Alumina..	·76	·28	·46
Silica and Insoluble	7·42	2·52	4·77
	99·74	99·99	100·11

In the gneiss which is in contact with the limestone, only two minerals occur of purity and size of crystals fitted for analysis. These are a dark mica, and a pale brownish white *orthoclase*.

A qualitative analysis showed the mica to be *lepidomelane*. It was in plates about three-fourths of an inch in size.

The felspar was in interpenetrating crystals of nearly uniform size; its specific gravity is 2·56. As it occurred within twenty or thirty feet

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of the limestone, it was analysed to ascertain if the quantity of lime was in excess of that normal to the mineral.

It yielded—

Silica	64·23
Alumina	18·682
Ferric Oxide	1·318
Lime	·69
Magnesia	·384
Potash	12·377
Soda	1·256
Water	·705
	99·642 (H.)

It can hardly be said that there is here any marked increase in the normal amount of lime.

In the contact zone there was found the following large assemblage of minerals,—

Biotite, common.	*Apatite, rare.*
Actinolite, rare.	*Chlorite, rare.*
Augite, (Funkite).	*Asbestus, common.*
Pyrite, rare.	*Tremolite, rare.*
Sahlite, common.	*Steatite, rare.*
Andesine, rare.	*Talc, very rare.*
Sphene, scarce.	*Pyrrhotite, scarce.*
Molybdenite, very rare.	*Malacolite, common.*

These are arranged in the order of their occurrence from without inwards, in the rock.

A point of much interest here is the occurrence, so near to one another, of the three varieties of the one mineral,—the dark-green *Funkite*, the pale sap-green *sahlite*, and the milky *malacolite*. These in no way pass into one another,—they are perfectly different in appearance; occur invariably in different positions; and differ much in the size of their crystals.

Another point of note is the paragenetic occurrence of the *hornblendic* type of mineral; this also presents itself in three varieties, which do not shade into one another,—*actinolite, asbestus, tremolite*; these also differ entirely in appearance. It must be here noted, however, that I have offered no proof, analytic or otherwise, that the asbestus and tremolite are not of the augitic type of mineral.

The first mineral noted above is *Biotite*. This frequently forms a solid crust between the gneissic rock and the contact zone; this crust seems to consist of little more than a dense mass of minute flakes of the mineral.

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Rarely it occurs in large rich-brown flakes in the chlorite, and more frequently in smaller ones of a light greyish-brown colour. The smaller crystals are superimposed upon one another, so as to have a foliaceous appearance; this variety also coats crystals of sahlite.

As the peculiar greasy lustre of these pale crystals gave some hope of their being *phlogopite*,—a mica which I have not yet found in Scotland,—they were analysed, and yielded

Silica	39·769
Alumina..	16·676
Ferric Oxide..	·653
Ferrous Oxide	6·73
Manganous Oxide	·615
Lime	2·196
Magnesia	20·923
Potash	6·5
Soda	·476
Water	5·398
	99·936 (H.)

being thus merely Biotite.

The specimens of *actinolite* were dark-green in colour, they were in interlacing imbedded crystals associated with *Funkite* and *Pyrite*. They were rare, and inferior as specimens. The *Funkite* was also in imbedded crystals of about an inch in length, by half that width; it was in four-sided crystals, but their terminations were obscured. Cubes of pyrite occurred along with these, and pyrrhotite in larger amount was also here associated. It was massive only.

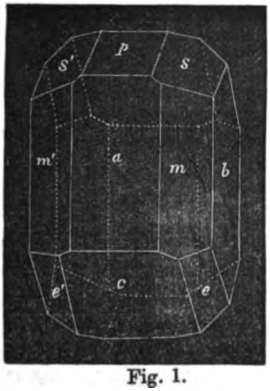

Fig. 1.

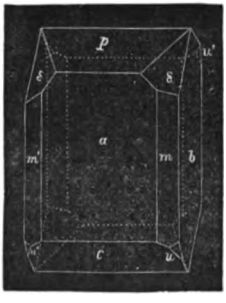

Fig. 2.

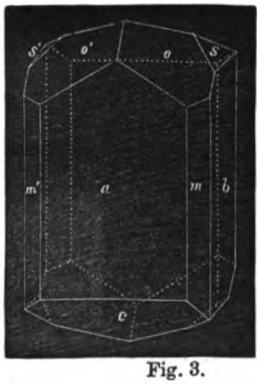

Fig. 3.

Sahlite occurs in great quantity generally in interlacing foliaceous crystals, but sometimes in flat crystals, imbedded partially in limestone; these are disposed one over the other, with half an inch of limestone

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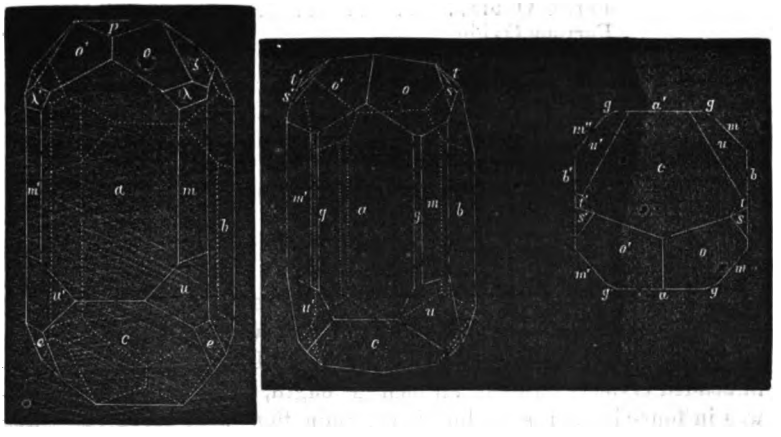
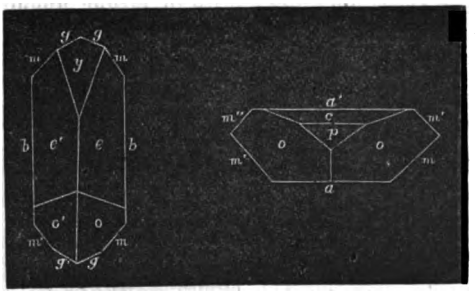
intervening: they are an inch in thickness by several inches in length and breadth. We were not so fortunate as to break up the masses of lime in such a way as to obtain the terminations of these large crystals; some, which were placed in acid in large mass, gave only rough terminations; but the surfaces of the large crystals were occasionally studded with small individuals, five forms of which are depicted. These crystals had a dull sap-green colour; but occasionally equally large crystals were of a fine grass-green.





Occasionally the small crystals of sahlite have their faces so abnormally developed as to appear distorted, and to be with difficulty recognisable.

The summits of the two extreme forms of such are drawn in the same position.

Cavities of any notable size rarely occur in the massive lumps of the sahlite.

A very few of the larger of these contain a felspar, of which I had not enough for analysis. This, from a chemical determination of the felspar of the granular limestones in other parts of Scotland, where it invariably has proved to be *andesine*, I assign to that mineral.

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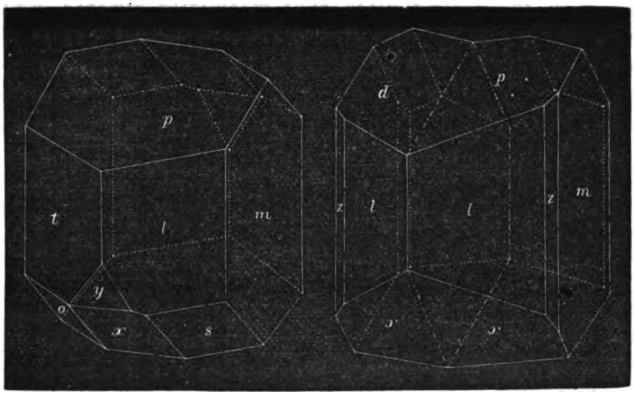

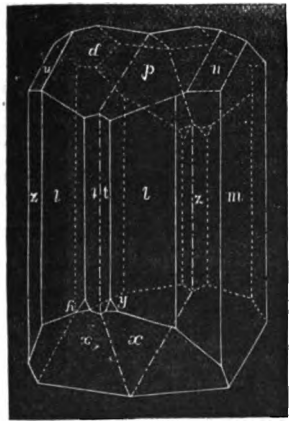

I was able to draw three of the forms in which this felspar occurs—one simple crystal, and two twins; these forms would equally well accord with the mineral being *albite*, but, for the above reason, and another immediately to be stated, I prefer to consider it *andesine*.

The crystals have the colour and lustre of bleached wax, or cold suet; they are of the size of peas or small bullets; they show striation occasionally.

A point of very great interest connected with them is this;—a specimen of sahlite which had a cavity plugged with calcite, happened to have been placed in acid stronger than that which was usually employed for the removal of the lime carbonate. When the action was at an end, it was found that the cavity contained several of the felspar crystals, and all had their composite striation-structure disclosed through *the alternate layers* having been dissolved almost entirely away. A series of thin plates remained; these also had been slightly acted upon.

So much had the plates been dissolved away, that the crystals upon another specimen were tried gently with a knife, and touched with acid to see whether it was not possible (however improbable), that the alternate layers were calcite. This they were found not to be.

Here is a most valuable piece of information.

It shows firstly that the crystals could not be *albite*; for *it* is insoluble in *strong* acid, even when in powder. The acid used was about one of chlorhydric acid to four of water.

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It shows in the second place, that sometimes striated crystals of felspar are *made up of alternate plates of two homœomorphous felspars.* In this case one was soluble in weak acid, while the other was not.

The question now presents itself. Supposing it to be *andesine* in composition, is that composition, and is the crystal-fabric, made up of alternate and reversed layers of *anorthite*, which is soluble in acid,—and of *albite*, which is not?

Unfortunately I have not enough of these crystals to decide this by the aid of chemistry. They differ in appearance from such of the limestone andesines as I have analysed;—first in their being regularly and perfectly crystallised, and secondly in their waxy translucency; those from other localities being milky and opaque. There are however trifling distinctions.*

The *Sphenes* of Shinness are certainly the finest in Britain, at least as regards their form. One specimen also was the largest crystal which I have seen from Scotland. This was a crystal of simple form, which we found exposed on the roadside. As this crystal seemed to be somewhat loose in its matrix of sahlite, it was measured, and found to be two inches in length, by one in width; it was of a pale-yellow colour. In "dressing" the specimen the crystals started in fragments from the stone. Its specific gravity was 3·617.

The fragments were analysed and yielded—

Silica	34·666
Titanic Acid	35·464
Alumina..	2·897
Ferric Oxide..	tr.
Manganous Oxide	·499
Lime	26·853
Magnesia	tr.
	100·378 (H.)

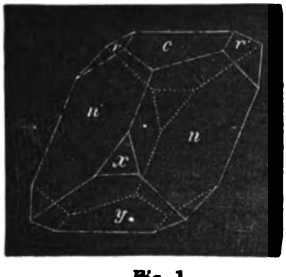

Fig. 1.

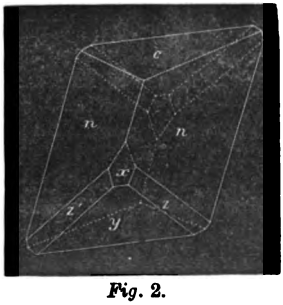

Fig. 2.

In general however, the sphenes are not half the size of peas. With the exception of the before-mentioned crystal, they are all of a dark hair-brown colour.

* I have since treated the andesine from Urquhart and that from Dalnein—both of which analysis has proved to be andesine, and both of which are striated—with acid of one to four of water, and also with strong acid, without observing any effect.

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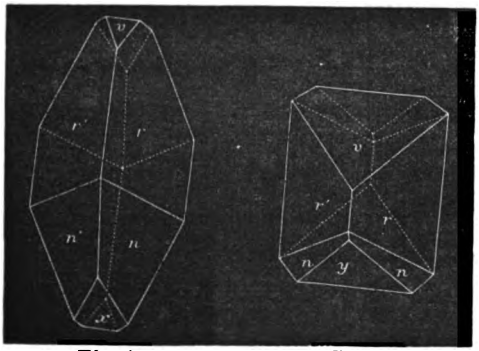

Fig. 4. Fig. 3.

They are seldom of simple form. Figures 1 and 2 show the simplest.

A difference of dominance in the faces *n* and *v* occasions the diversity of appearance shown in the figures 3 and 4, which are nearly the same form.

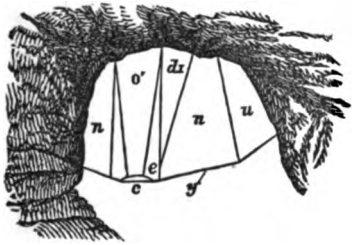

Fig. 5.

In the very complex form, figure 5, the crystals are so imbedded in the matrix that some of the faces have been somewhat conjecturally lettered.

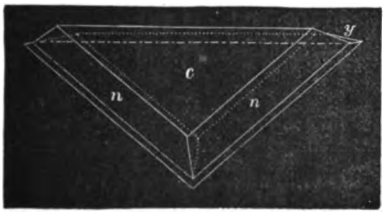

Fig. 1.

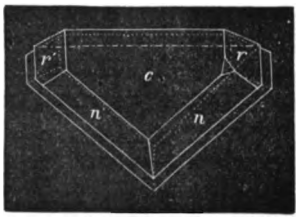

Fig. 2.

In the twin forms,—which are nearly as frequent as are the simple

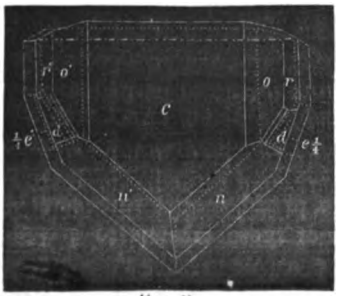

Fig. 3.

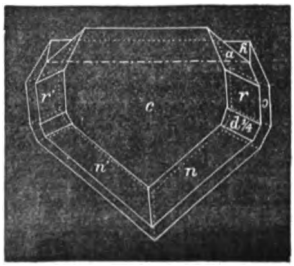

Fig. 4.

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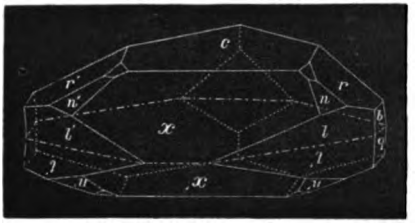

Fig. 5.

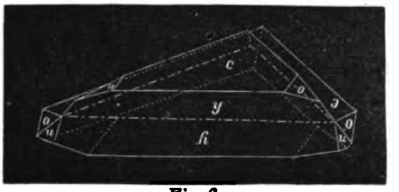

Fig. 6.

crystals,—the face which truncates the angles of *n c r*, and which is seen in three of the crystals, would appear to be new. It is somewhat too rounded for measurement. Figures 5 and 6 are placed in an inverted position, in order to show a larger number of faces.*

The dark-brown sphenes yielded to analysis:—

Silica	36·789
Titanic Acid	35·393
Alumina	2·208
Ferric Oxide..	·284
Manganous Oxide	·299
Lime	25·403
	100·376 (H.)

The cavities which held these sometimes also contained crystals of *Biotite*

Molybdenite is very rarely associated with the sahlite. Sometimes in plates imbedded in it, sometimes in rosette crystallizations perched upon the surface of its crystals.

The annexed form was seen; this, if correctly drawn, would leave some doubt as to its being hexagonal. The crystal however was extremely minute.

The *Apatite* which occurs here is also imbedded in sahlite; it is in fissured lumps of a pale asparagus green colour.

The only specimens I have seen of *asbestus* were sent me by Dr. Joass, but they must at one time have been found in great quantity, for some of it performed the function of "packing" to the other minerals sent me by him.

It was in fibres of several inches in length of a greyish straw colour and a high lustre. It was hard, rigid, and rough, though in

* In figure 6 the faces marked *o* should be *d*, in the *lower* half.

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other respects very similar to the valuable variety from Balta; it contained a little chlorite among its fibres.

It yielded—

Silica	56·864
Alumina	·232
Ferric Oxide	·484
Ferrous Oxide	2·124
Manganous Oxide	·23
Lime	12·535
Magnesia	23·923
Potash	·439
Soda	·538
Water	2·525
	99·866 (H.)

Dr. Joass also sent me long hatchet-shaped masses of closely-packed parallel fibres of a pale-green colour; these were somewhat amianthiform.

To Dr. Joass I am also indebted for a specimen of *tremolite*, which not only surpasses in beauty anything of the kind which I have seen from abroad, but which is one of the finest minerals ever found in Scotland. Nearly a foot in size in all directions, the mass is covered with parallel bundles of glancing fibres of the most delicate tenuity; these flash with a brilliant but chastened light, of more than silvery whiteness. No natural object devoid of colour could possibly be more beautiful. Its specific gravity is 2·964.

It yielded—

Silica	56·153
Alumina	·857
Ferric Oxide	1·617
Ferrous Oxide	·716
Manganous Oxide	·069
Lime	13·31
Magnesia	24·138
Potash	·441
Soda	·211
Water	2·5
	100·012 (H.)

It is not only possible, but very probable, from the small amount of alumina which replaces silica in these last two minerals, that they are both *augitic* minerals; the nature of their matrix also bears out such a view.

For the next two minerals also,—*steatite and talc*,—I am indebted to Dr. Joass; all of these occurred in a quarry which was exhausted

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before my confrere, Mr. Dudgeon, and myself examined the stratum; it is well for the records of Sutherland science, that so keenly observant an eye had been there before us.

This steatite is peculiar; it occurred in rounded nodules,—from the size of a marble to that of a golf ball,—one side of which lay directly in the calcite. It was massive, but had an obscure laminated structure; the colour of it was that of cream, blotched with pale blue. It was hard, cutting like slate pencil; from its rough surfaces there rarely protruded small crystals of *talc*.

This steatite is aluminous, it yielded—

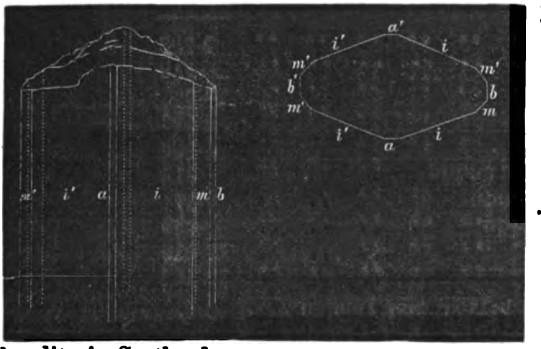
Silica	67·089
Alumina..	1·586
Ferrous Oxide	1·822
Magnesia	23·297
Water	6·048
	99·837 (H.)

Its specific gravity is 2·74.

Pyrrhotite occurs at this locality in perhaps smaller quantity than at any other of the primary limestone localities in Scotland. It is here generally associated with the darker varieties of augite, but seldom appears in the limestone, and scarcely ever sprinkled throughout it, in the manner usual to the mineral.

Indeed the same may be said of the last mineral I have to notice, viz. *malacolite*. The freedom of the general mass of this limestone from imbedded minerals does not give countenance to its having been a highly fossiliferous stratum; its purity indeed, entitles us to doubt its having been at all fossiliferous.

As the contact-zone merges into the limestone, *malacolite* of a dull yellow colour appears. It shows rarely the unterminated form drawn. The variety of this mineral which is actually in contact with the limestone, or is imbedded in it, occurs not only in larger crystals, but in much larger quantity than at any other locality in Scotland.



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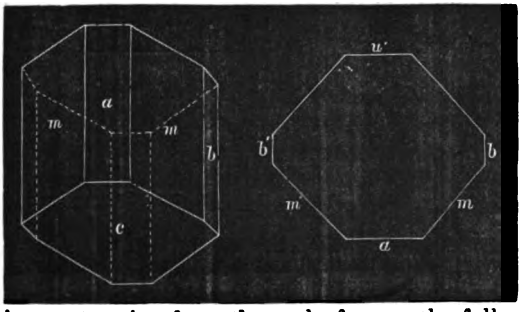
Though very seldom showing crystalline faces, being imbedded, it is here so pure in colour, so lustrous, and in such large masses, that this must be regarded as decidedly its best Scotch locality. Sometimes it occurs in distinct layers in the limestone.

Frequently it is found in widely radiating crystals; and single crystals a foot to sixteen inches in length, by an inch or two in breadth occur. These are frequently fissured transversely,—delicate amianthiform fibres of extreme tenuity and silky lustre, stretching across the gaps, sometimes a fourth of an inch in width, to connect the severed portions. These gaps are filled with transparent calcite.

The malacolite has a cleavage angle of 87° 5′, and a specific gravity of 3·149; it yielded—

Silica....	53·062
Alumina..	·193
Ferric Oxide	1·773
Ferrous Oxide	·47
Manganous Oxide..	·153
Lime	23·626
Magnesia	19·295
Water	1·546
	100·116 (H.)



The only crystalline form I have seen is the simple one drawn.

The *c* cleavages of the malacolite and sahlite of Shinness, and indeed of the malacolite of Scotland generally is so eminent that the crystals, during extraction from the rock, frequently fall asunder along it. This is not admitted to be a cleavage face by Brooke and Miller, being regarded as merely a line of opposition of a plurality of crystals.

These *c* cleavages are here, and at several other localites in Scotland, evident to the sight by a parallel lineation of the mineral. In the more transparent of the Shinness specimens this lineation appears as narrow opaque white bands; in the sahlites generally, as in that of Tiree, as lines which are not only opaque, but which have a depth of colour which is invariably paler than that of the general mass of the crystal. This parallel lineation also constitutes the most characteristic microscopic feature of the stone; but the writer has one

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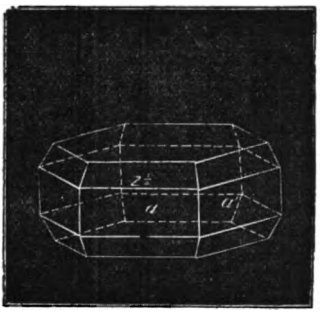
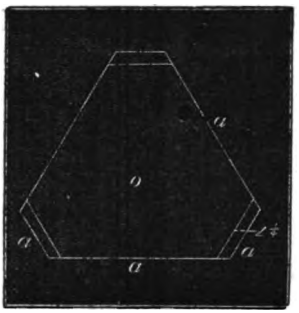
specimen which with polarised light exhibits a singular oblique-angled and crossed tartan pattern.

Arskaig.—The same bed of limestone, thrown up by a fault, appears at this locality on the south shore of Loch Shin. It here lies between two cross faults.

It has been mostly wrought out, but is more feebly developed than at Shinness. *Malacolite*, *sahlite*, *actinolite*, and *pyrrhotite* were seen here. Doubtless if it were still wrought, other substances would be found.

The pyrrhotite was occasionally in well-defined small crystals.





These had sometimes a hemihedral habit,—the more largely-developed of the faces *a* being in that case striated.

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Description of a Crystal of Euclase, belonging to my Collection.

By M. Guyot (de Grandmaison).

(*Read December 23rd*, 1880.)

THE crystal comes from the mining district of Boa Vista, near Villa Rica (Brazil), where the alluvial diamantiferous strata occur with chloritic schists. It exhibits great regularity in the disposition of its faces and in its physical characters.

Fig. 1.

Its total weight is 15·45 gm. Its dimensions are given by the scale shown on the woodcut (Fig. 1), which is of natural size. Its density is 3·087.

Colour, sea-green, like beryl; lustre, vitreous, nacreous on certain cleavage planes.

Fracture conchoidal, very fragile. Cleavage easy and perfect.

The prism is oblique rhombic, its angle 144° 37′; one termination is complete with numerous modifications, the other fractured, with traces of chlorite schist in the cracks.

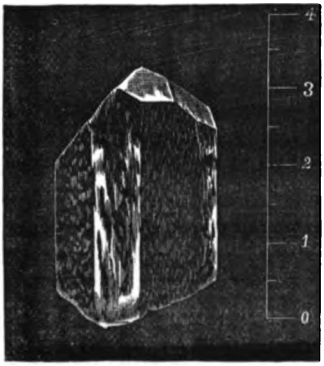

Fig. 2.

Strong double refraction, slight dispersion of the axes.

Inclined dispersion manifested by the unequal brilliancy of the colors in the two systems of rings.

Some of the faces of the vertical zone striated parallel to their mutual intersection, easily seen on the face to the right (Fig. 2).

Becomes electrical on the least friction, and even on simple pressure.

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Note by J. H. Collins, F.G.S.

With this note M. Guyot has sent a series of photographs and a cast of the stone. The measurements which I have been able to obtain from this are, of course, not very accurate, but they show that the following planes are present.

a. 100. a narrow plane.
a'. $\bar{1}00$. a wide well-developed plane.
b. $0\bar{1}0$. apparently a large cleavage plane.
c. 001. doubtful whether present or not.
s. $11\bar{0}$. a large well-developed plane.
s. $\bar{1}10$. a well-developed plane, but smaller than the last.
k. $21\bar{0}$. a large well-developed plane.
k'. $\bar{2}10$. a narrow plane.
f. 131. a rather small plane.
f'. $1\bar{3}1$. a large plane.
f''. $\bar{1}\bar{3}1$. a very large plane.
r. 311. a small plane.
o. $12\bar{1}$. a small narrow plane.
o'. $1\bar{2}1$. a small narrow plane.

The crystal appears to be a portion only of a still larger one—but it is evident that it was always hemihedrally developed. It is certainly one of the very finest specimens of Euclase which has ever been discovered, and M. Guyot authorises me to say that he will be at all times pleased to show it to his fellow-members.

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Reviews and Notices.

MONETITE AND MONITE FROM THE ISLANDS MONETA AND MONA, W. I. (By C. A. SHEPARD, *Am. Journ. of Science*, May, 1882.)—*I. Monetite.*—The mineral from Moneta, which the author names monetite, occurs in a guano-formation, lining the walls of cavities, sometimes in isolated patches, half the size of one's hand. More rarely occurring in botryoidal shapes, with rough crystalline surfaces. Colour, pale yellowish-white. H = 3·5, S.G = 2·75, which is a little below the actual, from the impossibility of clearing the crystals of the nearly white monite and gypsite, by which they are coated.

Primary form, right oblique angled prisms M on T about 143°. Secondary forms, terminal and acute lateral edges, replaced by single planes, the former generally very narrow. The surfaces of the crystals are without striæ or curvatures. The cleavage indeterminate. Fracture, uneven. Lustre, vitreous. Semi-transparent.

In a glass tube before the blowpipe turns white, and evolves a mixture. In the platinum forceps turns white, and melts into a globule with crystalline facets.

Composition :—

	I.	II.	mean.
Lime	39·92	40·59	40·255
Phosphoric acid	44·41	49·79	47·100
Sulphuric acid	7·20	1·90	4·550
Water	8·47	7·88	8·175
	100·00	100·16	100·088

2.—*Monite.*—Found intimately associated with monetite, is a hydrated tricalcic phosphate, resembling in colour and density the more friable varieties of kaolinite.

Characters: massive, slightly coherent, impalpable, and wholly uncrystalline; colour: snow-white, fracture earthy, dull; hardness below 2, S.G = 2·1 (approximately). B.B. melts with difficulty to an opaque, white enamel of feeble lustre. In closed tube emits much moisture.

Analyses :—

				mean.
P_2O_5	40·39	39·41	39·75	39·86
CaO	50·04	50·89	49·51	50·15
SO_3	—	2·57	1·75	2·16
H_2O	—	—	7·56	7·56
				99·73
Deducting 2·16 SO_3 = 1·51 CaO = 0·97 H_2O = gypsite ..				4·64
				95·09

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The monetite is the most abundant species, occupying areas several inches long. The interspaces between the crystals occupy as much room as the crystals themselves; and are more or less filled up with the monite.

The associated gypsite is white, in small shining crystals, coarse fibrous individuals, small globules, fine granular and pulverulent.

The presence of silica, or some insoluble silicates, is detected in the analyses of the aggregates only, where it varies from 0·5 to 2· per cent.

Note on Crystals of Monetite.—The crystals of monetite placed in my hands may, with tolerable certainty, be referred to the triclinic system. The general form is that of a rather thin rhomboid. The longer lateral edge is replaced by the plane 100 (*a*), and the shorter by the hemi-prism, $1\bar{1}0$ (I); there are also present in this zone the brachy pinacoid 010 (*b*), and two other hemi-prisms $h\bar{k}o$ (m and n) between 100 and $1\bar{1}0$, and a third hko (*l*), on the other side of 100. The top of the tabular crystals is formed by the basal plane 001 (*c*) which is rough and uneven, and the edge behind, between *a* and *c*, is replaced by a dome $\bar{1}01$ (*o*). The angles measured with the reflecting goniometer are only roughly approximate, and would not justify an attempt to calculate the axial ratios and inclinations. The supplement angles are: *a*I (100-$1\bar{1}0$)=42°, *ab* (100 010)=81°, *am*=17°, *a n*=21°, *a* l=18°, *a c*=76°, *a o* (100 $\bar{1}01$)=138°. There appears to be a distinct cleavage parallel to *a*. The crystals often interpenetrate each other, forming complex groups, but there is no uniform law of composition.—E. S. DANA.

T.J.G.

PHILADELPHITE—A NEW MINERAL.—(H. C. LEWIS, *Jahrb. f. Min.* 1881. 2 Ref. 339; *Journ. Chim. Soc.*, Feb. 1882).—Pearly lustre; brown or yellow colour; the thin lamellæ are flexible; monosymmetrical. Cleavage basal; also in two directions parallel and perpendicular to the plane of the optical axes. On heating increases in volume tenfold. Comp:—

SiO_2.	TiO_2.	Al_2O_3.	Fe_2O_3.	V_2O_5.	FeO.	MnO.
35·73	1·03	15·77	19·46	0·37	2·18	0·50
NiO, CaO.	CaO.	MgO.	CuO.	Na_2O.	Li_2O.	K_2O.
0·06	0·08	11·56	1·46	0·90	Trace	6·18
P_2O_5.	Cl.	H_2SO_4.	H_2O.			
0·11	Trace	Trace	4·34			

Formula $R^{II}_3\ R^{VI}_2\ Si_5\ O_{20}\ 2\ H_2O$.

T.J.G.

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Cyprusite.—(P. F. Reinsch, *Proc. Roy. Soc.*, xxxiii., 119, 1881.)—A supposed new mineral, composed chiefly of ferric sulphate, from the island of Cyprus.

Colour, yellowish. H=2. G=1·7. Partially soluble in water, soluble in boiling H.Cl., leaving a siliceous residue. This mineral contains a large percentage of well-preserved shells of microscopic Radiolaria.

Approximate analysis :—

Ferric oxide with alumina	51·5
Sulphuric acid	21·5
Residue insoluble in HCl (silicate, &c.) ..	25·0
Water	2·

T.J.G.

Cossyrite.—H. Forstner, *Jahrb. f. Min.*, 1881, 2 Ref. 332—334; *Chem. Soc. Journ.*, February, 1882.)—A new mineral from Lipartite Lavas, of the island Pantellaria. The crystals are generally twins, 1·5 m.m. long; colour black, with vitreous lustre on the prismatic faces, the others dull. Cleavage parallel to 2 prismatic faces, which make an angle of 114°9′. Crystalline system, symmetrical with the axial relations, a : b : c = 0·6469 : 1 : 0·6635.

Composition :—

SiO_2.	Fe_2O_3.	Al_2O_3.	FeO.	MnO.	CuO.	CaO.	MgO.	Na_2O.
43·55	7·97	4·96	32·87	1·98	0·39	2·01	0·86	5·29

K_2O 0·33 = 100·21.

S.Gr. = 3·74—3·75. T.J.G.

Analysis of Thorite from Hitterö, (G. Lindström, *Jahrb. f. Min.*, 1881, 1 Ref. 29; *Chem. Soc. Journ.*, March, 1882.

Silica	17·47	Manganous oxide	0·43
Phosphoric oxide ..	0·93	Alumina	0·12
Lead oxide	1·26	Lime	1·39
Thorium	48·66	Magnesia	0·05
Yttrium earth	1·58	Lime	0·18
Cerium	1·54	Soda	0·12
Ferric Oxide	6·59	Loss by ignition	10·88
Uranous oxide	9·00		100·20

This agrees with the analysis by Nordenskjöld of the thorite from Arendal.

Beegerite.—(Konig, G. A., *Am. Chem. Journ.*, ii., 379, 1881).—A new mineral, found in small crystals associated with quartz, on the Baltic lode of the Geneva Mining Company, at Grant Port office, Park Co., Colorado.

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The crystals are regular combinations of the cube and octohedron, elongated in the direction of an octohedral edge. Very distinct cleavage. S. Gr. = 7·273. Colour light to dark grey. Lustre brilliant metallic. Heated in a matrass, it decrepitates and melts at a read heat without subliming, in the open tube gives off sulphur dioxide, and at a strong heat traces of a white sublimate (antimony). On charcoal gives the reactions for lead and bismuth. The residue gives, with borax, a slight copper reaction. Dissolves in warm HCl.

S.	Bi.	Pb.	Cu.	
14·97	20·59	64·23	1·70	= 101·49.

ANNERÖDITE.—W. C. BRÖGGER, *Geol. För. Förh.*, v., 345, 1881.)—A new mineral found in the pegmatite vein at Anneröd, near Moss, Norway, associated with monazite, apatite, beryl, topaz, magnetite, &c. Colour black, streak blackish-brown or greenish-grey, opaque, except in very thin splinters. Fracture sub-conchoidal, H = 6. S.Gr. = 5·7. Found crystallized in groups of parallel fibres or radiated. Fuses on the edge with difficulty to a black glass.

Niobic oxide	48·13	Ferrous oxide	3·38
Stannic oxide	0·16	Manganous oxide	0·20
Silica	2·51	Lime	3·35
Zirconia	1·97	Magnesia	0·15
Uranous oxide	16·28	Potash	0·16
Thorina	2·37	Soda	0·32
Cerium oxides	2·56	Alumina	0·28
Yttrium	7·10	Water	8·19
Lead oxide	2·40		99·51

Orthorhombic axes—$\dot{c} : \bar{b} : \breve{a} = 0{\cdot}36103 : 1 : 0{\cdot}40369$.

SCHNEEBERGITE, A NEW MINERAL.—(A. BREZINA, *Jahrb. f. Min.*, 1881. *Ref.* 321—332; *Journ. Chem. Soc.*, Feb. 1882.)—Occurring in gypsum and anhydrite; locality Schneeberg in Tyrol. Found crystallised in transparent honey-yellow octahedrons, imbedded, with glassy to adamantine lustre. H = 6·5; S. Gr. = 4·1. Decompose with great difficulty by fused sodium potassium carbonate, was found by qualitative analysis to consist essentially of antimony, lime and iron, with traces of copper, bismuth, zinc, magnesium, and sulphuric acid. The crystals when containing enclosures of magnetic iron exhibit in polarised light a black cross, which is sometimes surrounded by concentric rings.

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DIOPTASE from Arizona. (*Am. Journ. Science, April*, 1882.)—Brilliant crystals of this mineral have been recently found lining cavities in what is called locally the "mahogany ore," a dark-brown compact mixture, consisting principally of limonite and oxide of copper in varying proportions, occurring at the Bon Ton group of mines, near the head of Chase Creek, about nine miles from Clifton Arizona.

SMALTITE from Colorado, (By M. N. ILES. *Am. Journ. Science, May*, 1882.) A sample from the surface croppings, recently discovered near Gothie, Gunnison County, Colorado, yielded :—

CO	11·59
Fe	11·99
As	63·82
SiO_2	2·60
Pb	2·05
S	1·55
Bi	1·13
Cu	0.16
Ni	Trace
Ag	,,
	(94·89 ?)

A purer sample yielded 15 per cent. cobalt.

T.J.G.

ON THE BERYL FROM CRAVEGGIA, PIEDMONT, (By Prof. G. SPEZIA. *Atti della R. Accademia delle Scienze di Torino*, Vol. XVII, 1882.) The beryls occur with tourmalines and manganese garnets in loose blocks of gneiss near Craveggia in the Val Vigezzo. Prof. Spezia gives an analysis of the mineral, which contains 11·49 per cent. of glucina. C. L. N. F.

GEOLOGICAL and MINERALOGICAL NOTES on the GNEISS of BEURA, (By Prof. G. Spezia. *Atti della R. Accademia delle Scienze di Torino*, Vol. XVII, 1882.) The quarries near Beura in the Ossola Valley, which have been worked for many centuries, furnish slabs of gneiss for making balconies, steps, and pavements, and as they are situated the banks of the river Toce, the stone can be put upon barges at once and sent by water to Milan.

The Beura gneiss is so fissile, that slabs may easily be obtained 20ft. long by 5ft. or more wide. At the Durodossola Museum there is a slab 9ft. long by 10ins. wide, of a uniform thickness of only $\frac{1}{8}$ inch.

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There are two principal varieties of the rock, one contains a considerable quantity of schorl, and may best be described as a tourmaliniferous gneiss; the other is dislinguished by the felspar appearing in the form of nodules when seen in a section at right angles to the plane of stratification. Prof. Spezia gives a long list of minerals which occur either in cavities or joints in the gneiss or disseminated through it, and he points out many interesting details concerning them. The memoir is a valuable contribution to the geology of the Ossola Valley, and affords ample proof that the author is a worthy successor of the late Prof. Gastaldi. C. L. N. F.

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THE MINERALOGICAL MAGAZINE

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On a New Mineral Locality.

By Dr. HEDDLE.

[Read June 3rd, 1882.]

IT is but seldom, at least in the experience of the writer, that a new mineral locality is now found in this country. By a mineral locality I mean, not a spot where one or two specimens may be gathered, but one at which there is a supply sufficient to entitle it to be recorded as a spot likely to be productive to a sequence of gleaners; and such as holds out hopes of its yielding specimens of more than average excellence.

The spot which I now notice was found by me during what I might call a passing visit; and as I had not an opportunity of thoroughly working it out, it offers to the collector a more than ordinary harvest.

The locality, moreover, is one which is most enticingly situated in the following respects:—

It is within a very short distance of a comfortable little inn,* and it lies embosomed in the midst of scenery of unusual grandeur.

* I regret to say that this comfortable house is now no longer an inn, and that the old small building is again the only place of entertainment. Provisions and rugs—*impedimenta* worse than hammers—must be taken now.

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It is about three miles from the inn at Stainchol in Skye; which inn is now easily accessible during the summer months, as certain of the coasting steamers land passengers almost at its door.

Stainchol is about nineteen miles from Portree.

The Quirang, which lies still nearer to Stainchol, has long been known as a fruitful locality for minerals; but, while the writer can remember the time when both there and at the Storr every third or fourth bit of rock contained a specimen of one or other zeolite, interesting and instructive in some respect, so overflowing has been the stream of curio-pocketing scenery-hunters to these wondrous localities, that now scarce a crystal of any kind rewards a day's hammering.

Luckily the arrangements which have been made for visiting the Quirang from Portree give time only for a hasty rush to one spot of surpassing attraction, and so the locality to which I now direct attention has escaped.

There is some difficulty in describing its exact position, but the sketch which accompanies this paper will guide to it.

This sketch was taken from the north; and though the cliff-foot, throughout the ranges there seen, yields some few specimens, the spot of chief attraction is just below the two little sharp spikes which are seen on the left of the sketch.

In indicating it geographically, I would say that it is about a mile north of Quirang, and a quarter of a mile north-west of a deep round lakelet, which has only a subterranean escape for its blue-green waters.

It is a little corry among the cliffs, which will be at once individualised if the explorer but *lifts up his voice*, for the spoken words will be flung back to him in an echo of wondrous sharpness of articulation.

From the inn, the corry may be reached either by climbing the hill, and taking the little lake as a guide,—as the tint of its waters differs so markedly from the brown hue of that of the surrounding tarns;—or by taking the Quirang in the way, keeping along the cliff escarpment till the singular statuesque rocks called Leacan Fhionn are reached, and then, instead of climbing the summit of the sharp cliff seen in the sketch (Plate IV.), keeping *under* the line of cliff till the echo of the footsteps and the number of fallen masses of rock arrest attention.

Though the falls from the cliff have done much of the fracturing work necessary for the extraction of specimens, the collector must not imagine that he can pick them up here as he would pluck flowers, or that he will be able to cut them out with the trifling toys with which geologists as a class go about *tapping* the rocks. He has not far to carry his tools

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here, and must not begrudge the portage of workmanlike weapons. A mineralogist should always remember that while a fourteen pound hammer is, all things considered, the most convenient to carry, yet a seventeen pound one will do nearly twice as much work. It will, indeed, perform perhaps as much thorough work as more ponderous ones; for while a 42 lb. quarryman's mall will *break* a larger stone, there are but few men who can give both *speed* and *direction* to one heavier than seventeen, so as to *cut* a rock in a desired line.

The minerals which I found at this locality are:—*saponite; chabasite*, simple and modified twins; *gyrolite; plinthite; Thomsonite; Faröelite; mesolite*, in downy tufts and in red granular dense masses; *apophyllite; analcime; stilbite; Laumonite*; and small crystals which were either *chalcopyrite* or *tetrahedrite*.

Of these substances the *saponite* is the closest to the skin of the druse. The *saponite* here is very peculiar. It is of a colour passing from a brick-red to pale red, and to almost white;—rarely it is oil green. Its structure is in minute botryoidal groupings, and thin vein-like processes. The specimens are quite beautiful.

The *plinthite* occurs in three forms.

First, in beds among these strata,—beds of a few inches to nearly a foot in thickness. Here it may be regarded either as loam which when overflowed by lava-stream had been burnt into this clay-like layer; or as a product of change in some part of the rock mass itself.

Second, in the singular form of clusters of spheres of the size of peas, which have apparently an internally radiated structure. The dolerite of the Shiants, and a liassic argillaceous-schist in the same islands, show a similar structure. The surfaces of the spheres of the *plinthite* are rough.

Third, as a thin layer or band occurring among the zeolites themselves. Such a mode of occurrence I never saw before; and I therefore analysed this variety, in fear that I might have mistaken its nature.

When thus occurring, it lies above *chabasite* crystallised in simple rhombs; this *chabasite* tops an inferior layer of *saponite*. The *plinthite* is, in turn, capped in the druse in succession by *calcite*, by a second layer of *chabasite* in singularly complex twin-crystals, by *apophyllite*, *red mesolite*, *Thomsonite*, and *analcime*.

The *plinthite* falls to pieces in water, like *bole;* and it may, by this property and by its uniformly dense structure, be distinguished from the red massive *mesolite* which occurs along with it.

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Analysis of *plinthite*—		Thomson.
Silica	29·547	30·88
Alumina	19·027	20·76
Ferric Oxide	28·013	26·16
Ferrous Oxide	3·251	
Manganous Oxide	·844	
Lime	2·234	2·60
Water	17·891	19·60
	100·807	100·00

This *plinthite* loses 6·687 per cent. of the water at 212°. It appears to be a variety of *bole*.

Dr. Thomson's analysis of the Antrim mineral is appended for comparison.

The massive *mesolite* was to me an unknown substance, at least of this colour, until it was analysed. It occurs at the Storr of the same colour as here, though not commonly, nor in such large masses. At the former place it is found in flattish imbedded masses, and in small round granules,—both being in druses which are totally plugged by this one substance.

At Quirang, where this mineral is in large pieces, it not unfrequently is overlaid by large and fine opaque white crystals of *analcime*, forming specimens which are striking from the fine contrast of the colours. Sometimes it is directly underlaid by *red saponite*. Its structure is minutely granular, with a porous appearance. Its colour is nearly that of red blotting-paper, —passing however in parts to yellowish, or shading off to white. Its streak is nearly white. The hardness is 3·5, and the specific gravity 2·108. By some it has been considered as *plinthite*, but it has more resemblance to the red variety of *Lehuntite*.

Analysis of *mesolite*—	
Silica	45·615
Alumina	26·465
Ferric Oxide	1·428
Manganous Oxide	·884
Lime	6·116
Magnesia	·461
Potash	·567
Soda	6·905
Water	12·246
	100·178

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It loses ·9 per cent. of moisture at 212°.

The *Thomsonite* is generally disposed in minute clusters of flat crystals, arranged in a stellate manner, on the surface of the compact red *mesolite*. It is accompanied by *analcime*.

It differs from *Faröelite* in never forming solid spheres; and it much resembles primary *stilbite*. The mineral is colourless, and its lustre is less pearly than that of *Faröelite*.

Analysis of the *Thomsonite*—

Silica...	39·696
Alumina	29·949
Ferrous Oxide	1·43
Manganous Oxide	·076
Lime...	10·076
Potash	·878
Soda	5·511
Water	13·073
	100·189

It loses ·848 per cent. of moisture at 212°.

This is the first locality in Britain in which I have found *Thomsonite* in igneous rocks associated with beds of the Liassic period, though I had before found it in rocks of that age in Faröe. Subsequently I have recognised it as of common occurrence at Talisker, and as rare at the Storr.

There is another variety of *Thomsonite* which occurs here, but more abundantly at the Storr. The specimen, the analysis of which is subjoined, was from the latter locality. This singular and new variety is one of the substances which have been considered to be "*rock-soap*." It is, however, devoid of all soapy feeling, and indeed is rather rough.

It is found at Storr, filling small nests near the foot of the "Old Man of Storr." There are no minerals associated with it in the druses. It is colourless, or yellowish white; its structure is fine granular, and massive; hardness, nearly 5·0; specific gravity, 2·147 to 2·131.

Its appearance is that of a hard *kaolin*, or more like the above-mentioned allomorph of *mesolite*.

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Analysis of the variety of *Thomsonite*—

Silica...	39·016
Alumina	28·125
Ferric Oxide	8·281
Lime...	10·788
Magnesia	·646
Potash	1·01
Soda	8·709
Water	13·985
	100·505

There are two other closely adjacent mineral localities which can be visited from the Stainchol Inn. The first is a rocky gorge at the foot of the cliffs of Bioda Bhuidhe—the hill immediately to the south of the road to Uig. Here the same minerals occur as at the first locality. The second, the cliff foot of Ben Ethra, where *analcime*, *stilbite*, *chabasite*, and *gyrolite* will be found. A lately-opened quarry in Portree has yielded green *gyrolite*, white *gyrolite*, *apophyllite*, and *analcime*.

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On some Cornish Tin-stones and Tin-capels.

By J. H. Collins, F.G.S. &c.

THIRD PAPER.

[Read June 3rd, 1882.]

The Mineral Associates of Cassiterite.—These are much the same in Cornwall as have been observed in other tin-producing districts, as in Saxony, Bohemia, Brittany, Finland, Spain, the Malay Peninsula,* Banca, Blitong, Queensland, New South Wales, Tasmania, &c. In the following lists of minerals which are associated with Cassiterite in the different kinds of country-rock in Cornwall, I only refer (*a*) to those which appear to have been formed contemporaneously with the Cassiterite, and (*b*) to those which have been observed in immediate contact with it and mostly deposited upon it.

Granite.—Here the most usual associates as thus defined are, in the *a* class, besides the constantly occurring *quartz*, *felspar* (orthoclase, usually converted more or less completely into kaolin), *mica* (lepidolite, lepidomelane and the constantly occurring Gilbertite), and *tourmaline*; less frequently *wolfram* and *stannite*; and occasionally *topaz*, *apatite*, *Scheelite*, *fluellite*, *Tavistockite*, *Churchite*, and *molybdenite*. In the *b* class we have, besides *quartz*, *mispickel*, *pyrites*, *chalcopyrite*, *smaltite*, *blende*, *bismuth*, *bismuthinite*, *hematite*, and *limonite*, with occasionally *native-copper*, *pitch-blende*, and *uranium-ochre*. The reported occurrence of *chalcolite* (Torbernite) and *autunite* at Stenna Gwynn needs confirmation.

Elvan (Quartz and Felspar Porphyries).—Here, in the *a* class, besides *quartz*, *felspar*, and *mica*, as in the case of the rocks of granitic districts, we have *tourmaline* still more generally associated with the Cassiterite, but often only in microscopic crystals. In the *b* class I have only met with *quartz* and *hematite* as associates.

Killas (clay-slate, tourmaline-schist, "knoten-schiefer," &c.).—Cassiterite occurring in these rocks is invariably associated with *quartz* and microscopic or macroscopic *tourmaline*. Other frequently associated minerals in the *b* class are, *chalcedony* (Pednandrea, East Pool, &c.), *chlorite*, *mispickel* and *pyrites*; more rarely *wolfram*, *chalcopyrite*, *smaltite*, *cobaltite*, *hematite*, *limonite*, *blende* and *chalybite*; still more rarely *pitchblende*,

* P. Doyle, Quart. Journ. Geol. Soc. 138. May 1879.

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pearlspar, *pharmacosiderite*, *uranochre*, *chalcosiderite*, *Henwoodite*, *Andrewsite*, *olivenite*, *topaz*, and *apatite*.—The occurrence of *calcite* associated with *cassiterite*, which has been reported from Polgooth, seems to need confirmation.

Hornblendic slates.—Many so-called greenstones are really hornblendic slates, as at Botallack and Wheal Owles in St. Just, and Terras Mine, St. Stephen's. Oxide of tin is always very rare in such rocks. When it does occur its associates are *hornblende*, *actinolite*, *apatite*, *epidote*, *axinite*, *garnet*, in the *a* class; and *magnetite*, *hematite*, *chalcocite*, *chalcopyrite*, *diallogite*, *Penwithite*, *carbonate of bismuth*, *calcite*, *Dolomite*, *olivenite*, *scorodite*, and *pharmacosiderite* in the *b* class.

Greenstone.—In this rock the occurrence of tin oxide is very rare, but occasional veins of it occur associated with *chlorite*, *limonite*, and other products of change.

Origin of the various Forms of Tin-oxide.—I venture to think that, after a due consideration of the facts stated in reference to the large number of specimens described in my first and second papers, few if any of my readers will demur to the conclusion stated on page 4, *viz.* that all the different forms of native tin-oxide described have been deposited in their present situations from stanniferous solutions; all are aqueous or humid in their origin; none are in any sense igneous deposits. The frequent occurrence of minute crystals of Cassiterite lining fissures in quartz, which is frequently full of minute fluid cavities, would be altogether inexplicable on any other supposition. I have seen well-marked veins of tin-oxide, in crystals, where the whole vein did not exceed $\frac{1}{10,000}$th of an inch in thickness.

A difficulty, however, may be at first felt by some chemists in receiving this conclusion, arising from the well-known great insolubility of many tin compounds, and especially of the native tin-oxide. This difficulty will probably disappear when it is remembered that, although tin-oxide in its present state is very insoluble,* yet that some salts of tin, and notably the fluorides and chlorides (and possibly the borate) are very soluble in water.

The constant occurrence of *schorl*, *topaz*, and other minerals containing fluorine, with oxide of tin,—when it occurs in granite or porphyry, has led Von Buch, Elie de Beaumont, Daubrée, and other chemical geologists, to the conclusion that the tin has been brought into its present situation by the agency of fluorine; and Daubrée has even produced artificial crystals

* Recently precipitated tin-oxide is rather readily soluble in many menstrua, and I find that native tin-oxide (cassiterite) is very perceptibly acted upon by dilute *aqua regia*, especially when it is finely powdered.

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of oxide of tin by passing vapours of perchloride of tin and of water through a heated porcelain tube. The crystals so obtained did not appreciably differ from natural crystals of *cassiterite* in physical characters, although the "forms" were different. He used the perchloride instead of the fluoride simply because it was easier to get; but there can be little doubt that similar results would have been obtained by using the fluoride.

My examination of a very large series of Cornish tin-stones—many of which have been described in the foregoing pages—has proved that not only in granite and porphyry, but also in killas, a fluorine-bearing mineral (tourmaline) is invariably present in notable proportion. Chlorine also is usually present, although only in minute proportion, more especially as a constituent of the liquid occupying the numerous fluid-cavities always observable in vein quartz. Fluor-spar is not universal, simply because lime is a somewhat rare ingredient in the Cornish metalliferous districts, but locally it is tolerably abundant.

Daubrée remarks that it is difficult to specify the actual reactions which have taken place,* because we see only the final results of a series of changes. This is no doubt the case, but perhaps the action was not greatly different from the following:—

The granite being still at a high temperature, but a good deal fissured, and containing many shrinkage cracks, was exposed to the action of highly-heated water, or water vapour containing hydrofluoric acid, with occasionally hydrochloric acid, boracic acid, fluoride of tin, and other easily decomposable fluorides. As the fissures would naturally be more abundant near the outskirts of the several granite masses than elsewhere, the action would be greatest in these situations. The felspar would readily give up its alkali (and part of its silica also) to the acids or decomposable fluorides, being thereby reduced to the state of silicate of alumina (kaolin), while a part of the alkaline fluoride would be carried off by the waters, and another portion would be deposited as lepidolite and Gilbertite (some of the alumina being used up in forming these minerals) among the particles of kaolin. Where iron was present, if the fluids contained also boric acid the highly stable compound tourmaline would be formed, as we find it in great abundance. A somewhat similar action upon the *highly felspathic* killas near the junctions would probably result sometimes in the formation of tourmaline-schist, which pretty constantly occurs in such situations, and at other times in the production of the slaty varieties of tin-capel.

* Mémoire sur le gisement, la constitution, et l'origine des amas de minerai d'étain. *Ann. des Mines*, xx, 1841.

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Briefly, we may say that fluorine is every where present in the tin-producing districts of Cornwall, as well as boron and iron.* It seems to me, therefore, that the facts lend strong support to Daubrée's theory, and even extend its action to the killas tin-deposits. As might be expected, the stanniferous solutions have notably altered the characters of the neighbouring rocks, in some cases depositing silica throughout their substance (forming the so-called capels), in others depositing veins of crystalline or cryptocrystalline quartz; in others again carrying away a great part of the felspathic ingredients of the granite, and leaving the quartz in loose grains, so producing the "sand-lodes," such as have been described as occurring at Wheal Coates† and Great Beam Mine.‡

Still more commonly, in granite districts, the solutions have kaolinized the "country" to considerable distances from the lodes, not being able apparently to use up all the alumina in cases where the original rock contained much felspar. In all these instances the fluorine (and boron if present) appears to have become "fixed" in the form of tourmaline, Gilbertite and the other minerals mentioned above.

The Gilbertite. The constant and almost invariable occurrence of this greenish-yellow hydrated mica§ in the granitic "gites" of tin-oxide in Cornwall renders its composition a matter of some importance. It has been regarded as an altered (hydrated) Muscovite, but while Muscovite is one of the least alterable of minerals, it has been frequently noticed in immediate association with unaltered Muscovite. It has also been regarded as a variety of margarodite, and as an impure kaolin, but it differs essentially from both these minerals, and I am disposed to agree with Frenzel that it is a good and distinct species.

In colour it is greenish-yellow to yellowish-white; translucent to opaque; it occurs massive and also in spherical masses with radiated concentric structure; or in stellate groups; or, rarely, in six-sided tables. The hardness varies from 1·to 2·5, or perhaps 3; the specific gravity from

* See "*The Hensbarrow Granite District*, by J. H. Collins, Truro, 1878; and Foster, *Quart. Jour. Geol. Soc.* Nos. 135, 1878. See also Foster, Tin Deposits of East Wheal Lovell. *Trans. Roy. Geol. Soc. Corn.* 1875. p. 174.

† Davey, *Trans. Roy. Geol. Soc.. Corn.* iv. p. 484.

‡ *The Hensbarrow Granite District*, p, 39. It is observable that these loose crystal line particles of quartz, as well as those existing in the natural China clay rock *Carclazyte*), always have rough irregular corroded surfaces, as if they had been partially dissolved by some strong solvent.

§ Its occurrence in the tin mines of the Erzegebirge (Saxony and Bohemia) Zinnwald and Ehrenfriedersdorf is recorded by Frenzel, and noted by Dana in his Second Appendix (p. 24).

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2·6 to 2·82. It feels very greasy, and this character has often led to its being mistaken for talc. When heated in a matrass it usually becomes silvery-white and opaque; it gives off water, but only at a somewhat high temperature, and this water has usually an acid reaction from the presence of fluorine. Heated before the blowpipe it fuses, if in thin splinters or plates, tinging the flame red. It is pretty readily soluble in sulphuric acid, but hardly at all affected by nitric or hydrochloric acid. The following are analyses of Cornish specimens; the first by Le Hunt, the next three by myself. Nos. 1, 2 and 8 were from Stenna Gwynn, No. 4 from St. Just. The latter had a specific gravity of 2·78, and was part of a great vein of nearly pure Gilbertite, which was, in some parts, from 10 to 14 feet wide, and which contained microscopic crystals of topaz and a little Cassiterite.

	1.	2.	8.	4.
Silica	45·15	45·10	44·90	48·12
Alumina	40·11	86·00	85·80	84·90
Ferrous Oxide	2·48	1·10	·70	·65
Manganous Oxide	——	trace	trace	trace
Lime	4·17	1·50	1·60	·81
Magnesia	1·90	·90	·50	·22
Potash (with a little Soda)	——	11·40	10·40	9·71
Lithia	——	traces	traces	trace
Fluorine		·54	·72	1·42
Water	4·25	8·70	4·21	8·21*
	98·01	100·24	98·83	98·54

Le Hunt's analysis is manifestly wrong, as it gives the alumina much too high and shows no alkalies. Thomson gives an analysis of Gilbertite from Stenna Gwynn, containing 9·28 per cent. of soda, but I have never found any either there or at any other locality containing more than about 1·5 per cent.

The following analyses are quoted by Dana in his Second Appendix (p. 24). 1 was a massive specimen from Ehrenfriedersdorf; 2 a similar specimen from Pobersbau; and 8 a crystallised specimen from Ehrenfriedersdorf.

* Of which ·60 was lost at a temperature of 120° C.

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	1.	2.	3.
Silica	48·96	48·10	48·10
Alumina	30·96	32·30	31·55
Ferrous Oxide ...	2·24	3·30	3·10
Lime	0·26	0·40	1·30
Magnesia	1·97	1·12	1·38
Potash	8·47	10·02	8·62
Soda...	1·65	——	2·14
Fluorine	1·04	0·81	0·88
Water	3·83	4·09	3·52
	99·38	100·14	100·54

A comparison of these analyses with those given by Dana under Muscovite, headed "Margarodite (in part)," shows that his quoted analyses Nos. 3, 6, 19, and 27, may very well be included under Gilbertite, the only material difference being that the small quantity of iron present is stated as peroxide, whereas in the Cornish Gilbertites the equally small quantity of iron is present as protoxide. It is probable, too, that the "Margarodite" from Lambhoga, analysed by Dr. Heddle, and which is associated with kaolin, should be placed here.*

	a.	*b.*	*c.*	*d.*	*e.*
Silica	47·05	44·60	46·42	46·75	50·77
Alumina...	34·90	36·23	37·92	39·20	31·71
Ferric Oxide	1·50	1·34	0·46	trace	1·32
Manganous Oxide...	——	——	——	——	·23
Lime	——	0·50	0·67	0·39	·95
Magnesia	1·95	0·37	0·17	1·02	·79
Potash	7·96	6·20	9·63	6·50	5.11
Soda	4·07	4·10	1·54	——	·53
Fluorine	——	trace	——	——	——
Water	1·45	5·26	4·40	4·90	7·97
	98·88	98·60	101·21	98·82	99·38

In the last of these the deficiency of protoxide bases seems to be made up by the larger quantity of water present. The alumina is certainly

* The analyses referred to are as follows:—*a.* from Zillerthal (Dana, anal 3); *b.* from Litchfield, Conn. (Dana, anal. 6); *c.* from Ross Hill, Iowa (Dana, anal. 19); *d.* from Unionville (Dana, anal. 27); and *e.* from Lambhoga (Heddle, anal. 1, Chapters on the Mineralogy of Scotland, The Micas, p. 13).

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somewhat low and the silica high, but perhaps there was a small admixture of free silica present in the form of quartz grains; at any rate, this is often the case with the Cornish Gilbertites, as in the specimen from St. Just, referred to above.

The Tourmaline.—Several analyses of the tourmaline occurring in the granite of Devon have been published, but the following (*a* and *b*) are, so far as I know, the first analyses of Cornish tourmalines. The first (*a*) is of a specimen of radiated black tourmaline from the kaolin of Little Carclaze, analysed by my pupil and friend, Mr. F. Johnson, an Associate of this Society; the second (*b*) is a specimen from the Trevisco kaolin, analysed by myself. I add the well-known analyses of Mitscherlich (*c*) Gmelin (*d*) of fine crystals of black tourmaline from Bovey Tracey for comparison.

	a.	*b.*	*c.*	*d.*
Silica	46·12	43·22	37·00	35·20
Alumina...	18·40	23·14	33·09	35·50
Ferric Oxide } ... ... Ferrous Oxide }	21·90	20·87	{9·33 / 6·19}	17·86
Manganous Oxide	——	·10	——	0·43
Magnesia	0·50	0·40	2·58	0·70
Lime	0·40	0·51	0·50	0·55
Soda } ... ... Potash }	4·50	{2·10 / 2·34}	1 39 / 0·65	2·09 / ——
Phosphoric Acid	——	traces	·12	——
Boracic Acid	5·40	5·60	7·66	4·11
Loss on ignition	1·50	1·47	——	——
Fluorine and loss	·68	·25	1·49	3·56
	99·40	100·00	100·00	100·00

It will be seen that the principal differences are in the relative proportions of silica, alumina, and iron oxides.

Proportion of Fluorine in Tin-stones.—Taking the proportion of oxide of tin present in a given vein in granite to average 1 per cent. of the whole vein—not an unfair estimate, the proportion of Gilbertite to be 5 per cent. of the same vein, and the fluorine in the Gilbertite at 1 per cent. of its weight, we have then for 100 parts of tin-oxide, 500 of Gilbertite, or 5 parts of fluorine. This is certainly a low number, but if we bear in mind the fact that the Gilbertite extends into the country rock far beyond the limits of the workable tin, this dis-

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proportion at once vanishes, and there is seen to be fixed in the immediate neighbourhood of the Cassiterite an ample quantity of fluorine to have acted originally as the tin-carrier, and being set free to act on the felspar, &c., and to form the Gilbertite. Again, as regards the tourmaline, taking the oxide of tin, *e.g.* at Rock Hill, at $\frac{1}{2}$ per cent. of the total weight of the rock and the tourmaline at 30 per cent., both reasonable estimates, and farther reckoning only 1 per cent. of the tourmaline as fluorine, then 100 parts of Cassiterite correspond to 60 parts of fluorine, which is far more than sufficient for the purposes of the theory.

Even in the compact tin-stones of the deep tin mines of the Camborne district the fluorine will be found to bear not a very small proportion to the tin oxide present.*

Assuming, then (1), the former existence of such fluo-boro-chloro-stanniferous solutions, and (2) of fissures, cavities or shrinkage-cracks in which the new combinations might have a chance of taking place, we have evidently agencies quite sufficient to produce all the phenomena observed —capable of dissolving out and carrying away earthy minerals and of depositing Cassiterite and its associates in their places—either in a crystalline, cryptocrystalline, or amorphous form.†

That tin-oxide is still present in so many localities after such long periods of time have elapsed (the tin lodes being the oldest of the metalliferous deposits of Cornwall and Devon), and in spite of the subsequent circulation of mineral solutions of a different character, is manifestly due to the very fact of its permanency, *i.e.* its power of resisting the solvent action of these later solutions, which we have reason to suppose were destitute of fluorine.

With regard to the wood-tin, its frequent concentric globular or mammillary form would suggest that it was originally deposited in an amorphous form (and perhaps from a very concentrated fluid), like *limonite*, *psilomelane*, and the *calcite* of stalactites, in successive layers; these differences being due to changes in the nature or composition of the depositing solutions. The radiated structure would then be due to a further develop-

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* I found in one specimen 0·10 per cent. of fluorine, and in another 0·15 per cent. It is worthy of note that Delabeche, many years since, estimated the fluorine in the ordinary granites of Cornwall and Devon to amount to from 0·18 to 0·21 per cent.

† That the circulation of stanniferous solutions is still going on, or at least was so in geologically very recent times, is indicated by the occurrence of tin in the interior of a deer's horn (see *supra*, 2nd paper), and perhaps of that in the "alluvial faults" of Rosevear Moor.

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ment of the crystallising forces, exactly as observed in stalactites of carbonate of lime or sulphate of baryta. That such was really the origin of the radiated structure is indicated by the fact that the *tin-crusts* already referred to (see 2nd paper) possess a similar structure, although we can hardly suppose that the ingot of tin was originally oxidised on its surface in this particular form.

F. Becke regards wood-tin as merely an extreme form of needle-tin. I certainly cannot agree with this, as the latter is always remarkable for its extreme transparency and the former is equally remarkable for its extreme opacity. Moreover, there are no intermediate stages known, although we do sometimes see masses of wood-tin encrusted with acicular crystals of Cassiterite, and even find these latter occupying fissures in such masses.

With regard to the pseudomorphs from Wheal Coates, it has been very truly remarked by Mr. W. Mansell Tweedy in the paper already quoted,* that "these crystals appear to have been formed in matrices formerly filled with felspar," and "that disintegrating forces of great power have been in action in the immediate neighbourhood is evident from the extensive beds of sand and china clay which are found very near."

Source from which the Tin has been derived.—As to the source from which the tin was derived, whether it was brought up from some deep-seated deposit or layer in the earth's crust, or dissolved out from the surrounding rocks, as suggested by F. Sandberger† and others, further information is urgently needed on this point.

Evidence of a conclusive nature, however, will be very difficult to obtain. For, suppose the country rock originally charged pretty equally but in very minute proportion with some stanniferous compound capable of being dissolved out and re-deposited: then we might expect to find (1) that those portions of the rock immediately bounding the fissure or cavity in which the tin came to be finally deposited would be *more* highly charged than the main mass of the rock, while (2) those parts a little further removed would have *less* than the normal charge, the rock at a considerable distance from the fissures or cavities being (3) in its normal state, there being no way for the tin to make its escape. But the first modification would equally be met with if the tin arrived in the circulating channels from below, and the tin present in (2) and (3) is normally so small in quantity that it would be very difficult to find any difference; at any rate

* *Report Roy. Inst. Corn.* 1845, p. 20.

† *Ueber das Vorkommen des Mines in Silicaten*, von F. Sandberger, *Sitzb. d. K.K. Akad. d. Wiss. Wien*, 4 Mar. 1878. See also *Zeitschr. der deutschen geol. Gesellschaft*, 1880. Stelsner combats this theory.

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the most careful and minute microscropical and chemical investigations would be necessary before any conclusion could be arrived at.

There is, however, one class of facts which seems to indicate that the tin is derived from the country and not from deep-seated sources communicating with the country rock by fissures. I refer to the frequent occurrence in granitic districts of apparently isolated masses of Cassiterite. Some of these are occasionally of considerable bulk, and the idea they suggest is certainly that they have merely passed into a previously existing cavity or "vugh" from the surrounding country.

I must confess that I incline to this latter supposition, and I am glad to find that so eminent a mining geologist as Mr. J. A. Phillips, F.R.S., agrees with me.* In either case, given a fissure filled with fluo-boro-chloro solutions at a high temperature, and a compound of tin upon which those solutions could act, and it must be admitted that the fissures would probably become filled or partly filled with crystals of Cassiterite whether the original tin-supply was situated below or around.

* To what extent these deposits were produced by waters rising from below, and how far they were influenced by lateral percolation, cannot be determined. The effects produced on the contents of veins by the nature of the enclosing rock, and the frequent occurrence of deposits of ore parallel with the dip of the adjoining country, would, however, lead to the conclusion that lateral infiltrations must have materially influenced the results. Phillips, Q. J. Geol. Soc. 1875, p. 342.

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Analyses of a Variety of Saponite.

By J. J. Dobbie, M.A., D.Sc., Assistant to the Prof. of Chemistry, University of Glasgow.

[Read June 3rd, 1883.]

THE variety of *saponite* described in the following note was first obtained by Mr. Walter Burns, of the Geological Society of Glasgow, from a quarry in the Cathkin Hills, about three miles S.S.E. of Glasgow. The quarry is hewn out of dark-coloured dolerite, rich in olivine, which rests on beds of felspathic ash. The dolerite has in places been converted into a green-coloured fibrous variety of saponite (*Bowlingite*), which is found in veins of from 2 to 8 inches in thickness. This variety has been analysed by Prof. Heddle, as well as by Mr. G. Wallace Young and Mr. G. B. Hannay.*

The mineral to which this note refers occurs near the base of the dolerite, in irregular, lenticular, horizontal veins or patches which lie near the base of the quarry, about thirty feet below the surface, and swell out in places to a thickness of 6 or 8 inches. It is of a deep chocolate-brown colour, has a well-marked conchoidal fracture, a very uniform structure, and the soapy feel characteristic of most hydrated silicates of magnesia. When taken from the quarry it is dull, but slight rubbing with the soft part of the hand imparts to it a high polish. When placed in water it splits into sharp angled fragments, ultimately crumbling, and on this account its specific gravity cannot be determined with accuracy. Hardness about 2. Specific gravity of the powder about 2·214.

Some of the specimens contain numerous minute particles of foreign matter. These are probably crystals of carbonate of lime; at all events, analysis of the mineral shows that it contains carbonic acid; and, on examining some of the powder with the polariscope, numerous double-refracting particles are discernible amongst the opaque particles of the *saponite*. The mineral is much too soft to allow of transparent sections being cut.

When treated with hydrochloric acid, the mineral effervesces faintly, and dissolves, leaving a residue of insoluble silica. Chemically it is essentially a hydrated silicate of magnesia.

* See *Min. Mag.*, 1877, and *Trans. Geological Society of Glasgow*. Vol. II., p. 212.

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Analysis of three samples gave the following results :—

	I.	II.	III.
SiO_2 ...	40·07	39·90	40·81
Al_2O_3 ...	6·61	6·94	6·77
Fe_2O_3 ...	4·16	3·75	4·28
FeO ...	8·69	8·91	8·78
CaO ...	2·67	2·32	2·09
MgO ...	19·24	19·28	19·76
CO_2 ...	·38	·4	·36
H_2O ...	17·16	17·28	17·11
Alkalies...	trace	trace	trace
Total...	98·98	98·78	99·91

Water given off at 100° C, 18·02.

The following numbers give the average composition of *saponite*, as determined by Prof. Heddle, by analyses of specimens from thirteen different localities :—

SiO_2	40·68
Al_2O_3	7·18
Fe_2O_3	8·96
FeO	2·38
CaO	2·14
MgO	21·48
H_2O	21·76

Water given off at 100° C, 14·2.

It is evident from a comparison of these numbers, that the Cathkin Hill mineral is closely allied in chemical composition to the hitherto described varieties of *saponite;* the chief differences being the larger percentage of iron protoxide and the smaller percentage of total water. The amount of water, however, given off at 100° C., which Prof. Heddle considers an important character, is almost the same.

Looking to the differences in the composition of the rocks from which *saponite* is derived, and to the varying conditions under which its formation takes place, it is not to be wondered at that varieties differing somewhat in composition should from time to time be discovered. It is chiefly on account of its very remarkable physical characters that it has been thought worth while to call attention to this variety.

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The Geognosy and Mineralogy of Scotland.

By Professor Heddle.

SUTHERLAND.—Part IV.

The Igneous Rocks.

A very few dykes of the "greenstone type" are to be seen in the lower gneiss.

There are some localities at which the gneiss seems itself to have furnished the material of the dyke, if not to pass into it by insensible gradation.

One is a dyke seen in the vicinity of Badnaternag, on the north shore of Loch Assynt. Here the dyke runs along the strike of the rock.

A second locality is about half a mile south of Unapol. The dyke itself has here disappeared; but the gneiss in contact with it presents very singular features. Macroscopically it is massive and devoid of bedding; dark green in colour, sprinkled with a pale green, and almost aphanitic in denseness.

Under the microscope it shows its crystals of hornblende to be broken up in their centres by a minute sprinkling apparently of quartz and apatite. Only the fringes of these crystals are dichroic. There is little quartz in the rock. The felspar is striated, and contains much apatite. A black mineral is present in tortuous forms; it may be *iserine*. The rock appears to be undergoing a transmutation into an "igneous" one.

A true dyke occurs on the shore at Loch Inver. This Loch Inver rock is a *mélange* of equal sized crystals of augite, olivine, and a striated felspar. The augite is fine foliated, in ill-defined crystals, and, if iserine be excepted, free from endomorphs. The olivine is in comparatively small amount, and unaltered. The felspar is either in well-defined broadly striated or twinned forms, which are also minutely lineated; or it fills up the interstices of the olivine crystals as a hyaline glass. This is pervaded with needle hexagons, probably apatite. The opaque black substance, set down as *iserine*, is either embedded in the augite, or surrounds the felspar. The augite and iserine are rarely fringed with a highly dichroic substance, probably Biotite. The lineation communicates an appearance of oily softness to the crystals of the felspar, which renders the rock characteristic.

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Another dyke cuts the lower gneiss on the south-east shore of Loch Assynt. This is much serpentinised, though to appearance unaltered. The olivine is in much the largest amount; little of it being, however, unchanged. The augite is much altered, granular, and plugged by rounded crystals of altered olivine. The felspar is minutely granular, and pervaded with apatite (?) Much opacite is sprinkled everywhere. The manner in which the augite is riddled with olivine is the characteristic feature of this rock.

A third, more massive dyke, which the writer could not reach, is seen to cut the south-east bank of the same lake, near the point where it suddenly narrows at its western bend.

Apart from the granitic veins already noticed, the above, or similar dykes, are all the igneous rocks which I could find in this formation.

Apart altogether of their lithological nature, a very special interest attaches to the existence and modes of occurence of igneous rocks in a formation so deep-seated.

Professor A. Geikie has lately shown that one of the most recent outbursts of volcanic matter consisted of that extended system of dykes which cut, in parallel course, the rocks of the Western side of Scotland. Only a single outburst, indeed, has to be assigned to still more recent times;—namely, the lava stream which, now forming the pitchstone ridge of the Scuir of Eigg, had flowed into a river canôn, the exposed portions of whose bed disclose the truncated ends of several dykes belonging to the above system.

As the strike of this great system of dykes is but little removed from that which prevails in the high-tilted beds or banding of the Hebridian gneiss, and as the jointing between these beds is unusually free, it might have been expected that it would have been here developed in great force. Yet, if the map of Professor Geikie be examined, it will be found that, though the rest of the western shore-line is scored with red lines, those portions which represent the Hebridian gneiss and the conglomerates, are in this respect *a perfect blank*.

Perceiving the bearing which this fact might come to have in determining the relative age of certain of the formations of the north-west, the writer made some extended traverses, in order to ascertain whether this blank in Professor Geikie's, and in all the earlier maps, was to be assigned to the fact that these formations had not been examined, or to the fact that such dykes did not occur therein.

Among these traverses were the following :—On the Mainland, the shore line was followed from near the Ferry on Loch Erribol, round by Cape

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Wrath, to Rhiconich. From Loch Inver to Loch Polly. From Ullapool to Sand. In the Islands, the Hebridian rock was crossed from Stornoway to Tarbert, in Harris; and from Stornoway to Loch na Muilne. The coast line was examined, for the greater part, from Loch Carloway, on the West of Lewis, to Rodal in Harris. The island of Rum was walked round.

The result was that, while granitic dykes of quite different habit were found here and again in force, no igneous dykes other than those already recorded were found.*

As a fact, this must be considered significant; but significant of what? It will be answered,—the area subjected to the rending and eruptive forces did not extend so far North;—not further than Sleat in Skye, the limit of the red lines in that direction in Geikie's map.

Unfortunately for such a contention, the dykes are found in numbers cutting the Old Red in Orkney, and doing so with the strike normal to them elsewhere. In Shetland, dykes also cut the same formation, with the same strike; and in these Islands, a second significant fact is noted, namely, that not a single dyke cuts the formations which there occur and which are more ancient than the Old Red.

It is thus not by any limitation in *northerly* extension, that the absence of dykes in the old rocks of Sutherland and Ross is to be explained.

They are not limited in easterly extension; for, if they have not been traced from sea to sea, dykes certainly of this age have been traced into the Eastern sea.

Those of the west of the mainland enter the Western sea, and reappear in certain of the Islands, but in certain of them only.

They are very numerous in such as are composed of sheets of volcanic matter; but it must not be supposed that they only plugged rents formed by the shrinkage of a great cake of cooling lava, for they occur with a very similar frequency in that "upper-gneiss" which Murchison and Geikie have correlated with the Silurian.

Professor Geikie's map shows the *more northerly* portion of Sleat to be lined by them, and, in coasting along the *southern* stretch to the point of Sleat itself, I found that the number which there occur is very much greater than that of the more northern. Again, in examining rocks of the same formation from Corran Ferry to the Sound of Mull, on the east shore of Morvern, I found that they were so numerous as at some points almost to dominate in bulk over the rock which they invaded.

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* There are two dense hornblendic belts which somewhat simulate dykes in the cliffs of the west shore of Loch Carloway

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Dr. Macculloch has given a delineation of the manner in which the red sandstone of Strathaird in Skye is cut by the probable continuation of the dykes of Sleat; but no trace of these is found in westerly continuation to cut the Hibridian of North Uist or of Harris.

The dykes of Eigg point to Rum; there, one dyke is seen to cut the augite rock, but I could not find that a single one cuts the green flags of the so-called Cambrian rock.

It thus appears that these dykes in the north cut comparatively recent rocks, but do not cut the gneisses of Shetland. They cut the so-called Silurian or "upper-gneiss," and all more recent rocks lying away to the east; they do not cut the Hebridian gneiss by any extension to the west; nor is that rock cut at any medial point at which it appears.

Is it not thus rational to conclude that this system of dykes was *limited in depth*;—that the zone of the operation of the forces which gave birth to the material which forms the dykes, was superior to the Hebridian rock, and superior to the gneisses of Shetland?

I have never seen any igneous rock in the Torridon conglomerates.

The igneous rocks of the quartzite must be regarded as of unusual interest, as they may aid in settling the question as to the existence, in one part of the country, of an *upper* as well as a *lower* series of beds of that rock.

As the existence of a series of beds eastward and vertically superior in position to that which immediately overlies the conglomerate, is admitted,—and as that more easterly series has not yet been in any way *identified* with the more westerly, I shall meanwhile speak of them as the *lower* and the *upper*.

Igneous rocks of the Lower Quartzite.

The lowest of these in the series has already been noticed and described, as it is seen at the most westerly point of its occurrence, namely, near the summit of Canisp. It appears to be there not more than 100 feet above the Conglomerate. The large size, and the characteristic appearance of its crystals, as there found, have been noticed.

It is seen in much larger bulk, though of much less striking features, above the outcrop at An Cuileum, and on the slopes of Beinn Garabh, opposite to the inn of Inch-na-damff. Here it has been exposed, through denudation of the overlying beds of quartzite, over a great extent of the hill slope. It, and the quartzite, dip persistently to the E.S.E. Its

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characteristic features, both as regards size and definition of its crystals, —*orthoclase*, *albite*, and *pinite*,—are not here well pronounced; and there is a marked deficiency in the relative amount of orthoclase.*

The same red porphyry, with still smaller crystals of albite, and an almost total absence of crystallised orthoclase, is seen in the bed of one of the branches of the Allt an Uamh which flows due west from Braebag. It has here a dip to the W.N.W., and this is one of many evidences of the district forming a trough between Canisp and the Braebag ridge.

The second of the igneous rocks of the series is seen conformably bedded, a few hundred yards eastward of, that is above the bridge over the same stream, (the Cold Spring Burn). The bed of rock is only a few feet in thickness, and varies somewhat at different parts. It is dark green in colour, and markedly hornblendic throughout. There is presemt, indeed, sometimes little else than an interlacing of crystals of an actinolitic hornblende with a red felspar; the latter presents itself generally as paste; Pyrite, and a flaky substance, possibly pinite, are however also present.

Higher up the stream, a dyke—or possibly a *neck* of the same rock, cuts its bed, striking nearly at right-angles to its course; and, still higher up, there is, in a series of blocks which cross the stream, some evidence of a third occurrence of the same rock.

All of these lie palpably below the dolomite. To the east of it, and east also of Beinn-nam-Cueamhseag, a dome-shaped roll of the same rock is seen. It is exposed over a considerable space, rising from under quartzite to the west, and dipping below it to the east. On the west side of the south-west spur of Braebag, a distinctly interbedded band of the same rock appears at the low level of about 1,000 feet; while on the south spur itself, at about 1,600 feet, three beds are seen, which, with the intervening quartz beds, disclose admirably the double anticline into which the quartzite series is folded along the whole Braebag ridge. Of these eastern exposures it has to be said that they probably represent the beds seen in the Cold Stream Burn, brought up by the anticlinal roll; and it has to be noted of those on the south side of Braebag, that, in the paler colour and more foliated structure of the hornblende, they present a slight resemblance to some varieties of the "Logan rock." It is doubtless some of the same beds which, cutting through the hill, are to be seen on the north side of Miall Diamain; and in the fault at the Corry Dhu of Braebag a dyke of a somewhat similar rock is seen.

* A specimen was this year (1882) given me by Dr. Callaway, from near the shore of Loch Assynt, which has much *actinolitic hornblende*; and thus shows a transition into the igneous rock which occurs next in the series.

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Igneous Rocks of the Dolomite.

The next bed seen in rising on the series, occurs in the dolomite, among its lowest members. It occurs nearly immediately between two dark somewhat fetid and anthraconitic layers of the rock. It is admirably seen for nearly a mile along the stretch of the Stronchrubie Cliff. It is difficult to find the upper surfaces of any of these beds sufficiently exposed to enable conclusions to be drawn as to whether they are lava-flows, or intrusive; but a rude columnar structure, with rents of equal magnitude at the upper and under surfaces, which is seen in this bed, along with the uniformity of its structure and absence of all slaggy appearance, countenances the latter view.

This bed is very persistent. It is seen *all round* the Stronchrubie dolomite basin, wherever there is any extent of outcrop exposure; and, with its associated dark beds, it defines the limits of that basin better than do any of the beds of the dolomite itself,—characteristic as some of these are.

I have found it dipping W.S.W. in the Ledbeg River, about a mile above the bridge; N.E. on the South-west slopes of Ben-an-Fuarain; N. in the bed of a stream which flowed from the south side of that hill: N.W. on its South-east foot; W. on its East slope; W.N.W. on the North-east of Loch Maolloch Corry,—here twice seen through faulting. Mr. Hudleston found it in the stream above the Old Woman's Cave. It is again seen along a considerable line, North-west of the Cave of Dreadful Sounds, dipping S.S.W. to S.W.; on Cuil Dubh; and near the upper fork of the main stream of the Traligill River in Glen Dubh.

This bed, where last seen to the south of Inchnadamff, sinks beneath the turf,—the whole series being thrown into a downward flexure as it curves round to reappear on the slopes of the lower third of Cnoc-an-drien. A bed of the same rock rises out of till, which forms the stream-bank immediately to the north of the bridge over the Traligill river; but that this is the continuation of the beforementioned extensive bed can hardly be asserted, seeing that the outcrops to the north show in their ample exposure *a series* of igneous beds.

Crossing the Cnoc-an-drien section from the lake, a little north of the school-house, two are met, a short distance from the road, at a low level; and a third occurs at 550 feet, with only one thick bed of limestone intervening between it and the so-called upper quartzite. This here overlies the dolomite perfectly conformably, and without the smallest appearance of a fault.

The lowest of the beds near the road differs from that already described to a marked extent. It is of a blue colour; contains much *Biotite* with

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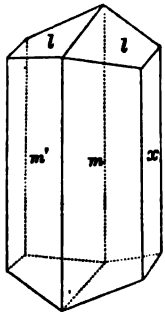
ferrite (?), and some hornblende; it also carries so much carbonate that it effervesces with acids.

That next in the series is seen as a neck. It forms a boss of considerable extent, which on the south distinctly cuts off a bed of granular quartzite. North of this, it throws out a narrow process between two dolomite beds, and here its constituents are best developed. The hornblende is so freely and distinctly crystallised in the form drawn, that the rock is a very beautiful one. Here the bed is not above a couple of feet in thickness; but it rapidly thickens, until where it is seen a little to the north it overhangs the road as a small cliff. Much granular pyrite, impacted in an almost granular hornblendic matrix, is now present; and the rock, especially to the south of the road, has become excessively tough.



The third bed near the quartzite is much of the same nature as that in the Stronchrubie Cliff.*

If the same series of rocks be traversed to the north, at the Chalda Burn, two beds in addition to those enumerated are seen. These lie between the second and third of the former series, and are undistinguishable from these in appearance.† Again, near the Traligill, the series shows two others, which lie below the second; so that some of the beds either die out, or thin off so as not to be readily found.

Amidst the turmoil and confusion which exists where this series of rocks is crossed by the Polandrien Burn, two dark and nearly vertical igneous beds are seen. They are of dense hornblendic material; and may be either dykes, or certain of the forementioned beds, altered by the crushing which is here evident.

There is a merely local dyke of red porphyry, similar to that of the upper quartzite, which cuts the dolomite very nearly on the line of its dip, on the flat east of Knockancliff.

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* It is, in no respect, of the nature of felsite, as stated by a late observer.

† The immediate, and what might be almost called *adhesive*, superposition of quartzite to dolomite at this locality, at an angle of 4° to 5°, must surely negative the view that a fault occurs here; while the absolute absence of any reappearance in inverted order of the argillaceous beds, within so short a distance as half a mile, is equally demolishing to the theory of an inversion of the whole series. The locality speaks plainly to the existence of an upper quartzite; there is neither need for fault, nor room for inversion.

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Igneous Rocks of the Upper Quartzite.

I have before mentioned how the lower quartzite of the ridge of Meall Diamain is, in the Col between it and Ben Bhrachaid, overlaid by slabs of the yellow argillaceous rock which underlies the dolomite; which slabby beds are in turn overlaid by what the writer believes to be the same rock as occurs in Glen Logan, near Loch Maree, in Ross-shire. It here forms the mass of Ben Brachaid—the rough, nodular, or "speckled" hill; and it has been described how, at the eastern end of this hill, the outcrops of three distinct beds of quartzite, somewhat slabby in feature as compared with the more granular rock of Meall Diamain, were to be seen.

This is certainly one of the localities which must be quoted as favourable to the existence of an *upper* quartzite, by those who hold such a view; and I therefore commence with it, in reviewing the igneous rocks which are to be seen in this series.

In passing up the section, though down the hill slope eastward to Loch Ailsh, there is to be seen an interesting series of beds; but as the section is best read in an opposite direction, *i.e.* from east to west, we will take it in that direction.

The west shore of Loch Ailsh is concealed by bog and cover, until we come, on the S.E. spur of Ben Brachaid, to the following sequence, in descending order:—

1. "Hornstone" porphyry, bedded. The "paste" is fine granular, glistening, and brownish-purple; the imbedded crystals are sharp-angled, isolated, "cuboidal," translucent, and like bits of hot suet. Very rarely they are pale green. The bed is about two and a half feet in thickness; its dip and strike accord with that of the system. Loose fragments of this rock weather so that the paste becomes cream coloured, and the crystals opaque white.

2. A second bed of the same, of about four feet. In this there are several layers of granular quartz. These layers are from half an inch to four inches thick; the grains are sharp-angled (? fragmentary) and of sparkling lustre,—it might almost be said vitrified appearance.

3. A bed of about one and a half feet of yellow fine-grained granular quartz. The grains are much smaller than those of the above, not so markedly fragmentary in appearance, and there is some appearance of rounding.

4. A bed, some inches only in thickness, of a rock similar to 6.

5. A bed of quartzite, two feet; like 3, but of a lively light-green tint. 3 and 5 have occasional specks of a soft ochre, but no pyrrhotite was detected.

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6. A bed, four to five feet, of a rock *banded* and *blotched* with the material of 1, throughout a matrix of a bright-green colour; which matrix consists chiefly of a coarsely-fibrous or crystalline green mineral, apparently hornblendic; with some crystalline felspar, and granular quartz.

7. Worm-hole quartzite. The beds are here thin, but they sweep up the hill-slope, and thicken into the beds on the east top of the hill.

8. Green (Logan) rock of Ben Brachaid.

The interest here centres in Nos. 1 and 6; 1 was accordingly analysed,—both the imbedded crystals, and the paste; these seemed alike pure. As the crystals were about half the size of peas, they could be cut quite free of the paste.

They yielded—

Silica	66·615	
Alumina	17·556	
Ferric Oxide	1·867	
Lime	·782	
Magnesia	·884	
Potash	1·880	
Soda	10·086	
Water	·729	
	99·799	(H.)

The paste yielded—

Silica	66·846	
Alumina	20·11	
Ferric Oxide	1·428	
Lime	1·038	
Magnesia	·807	
Potash	·441	
Soda	9·697	
Water	·888	
	100·195	(H.)

Both are therefore *albite*; and with such a similarity of composition, it is difficult to see how the paste should not have crystallised also. The rock has no claim to the name "hornstone." Those who hold this to be an igneous bed might argue that the formation of definite imbedded crystals in rocks, and the dimensions of these, are alike dependent upon a retardation of cooling. Standing on the spot, however, and having regard to the appearances seen in beds 2 and 5, the writer could come to no con-

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clusion, judging from their relationships alone, than that both would be generally regarded as metamorphic.

At and near the summit of Cnoc-an-drien,—(another locality which would have to be quoted in evidence of the existence of an upper quartzite)—there is, however, a rock, certainly not in hand-specimens to be distinguished from the above, which cuts at several spots right through (without in general disturbing) the beds of the upper quartzite. It is here in true dykes, two to four feet in thickness, and also forms knolls, which are apparently isolated from each other, among the lakelets on the top flat of the hill. No rock could be more clearly igneous. This *may* be different from that analysed. No analysis has been made, but, except in colour, the writer could perceive no distinction. The colour is a reddish chocolate, often padded or blotched with a pale olive skin; the crystals are here white.

The quartzite beds are cut almost vertically, and a vitrified crust of quartzite, bleached white, is *firmly adherent* to the porphyry. This crust is about eight inches in thickness, and is separated from the quartzite of the bed by a rent, sometimes gaping, which rent is nearly at right angles to the bedding of the rock. The writer never saw a finer illustration of rending, singeing, and cementing.

The appearances at the two localities are thus most perplexing, as a material seemingly one and the same appears to be *metamorphic* at one spot and *igneous* at another!

Again, among the shattered outcrops which protrude from the craggy south face of Coniveall, and indeed among fallen blocks at its foot, there are to be seen square cleft masses, one side of which consists of this porphyry, while the other is quartzite; and the lens can find no line of demarcation. The paste gets in among the quartz grains on one side, while an albite crystal may be found altogether away from the felspathic paste, lodged among siliceous granules. There is no sharp welding of side to side; if there is not a *transfusion*, it must be said that there is apparently a gradual passage from a loose-grained fragmentary rock to a vitreous paste. It must prove a perplexing inquiry to determine what was the nature of the genesis of such a rock.

It may be fairly expected that the observer should give some expression of his opinion, even if it should be an uncertain sound; but he considers that he has not yet data sufficient to enable him to form any such opinion as would be satisfactory even to himself.

Reverting to the bedded rock on the S.E. foot of Ben Bhrachaid, it has to be noted that it is by no means clear what these beds represent. They may represent a repetition—a lithologically modified repetition of the

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green, or "Logan Rock." Only *one* great bed of this overlies the quartzite of Meall Diamain, forming the hill of Ben Brachaid: but at least *four* beds of the same rock, some of which differ much from the others in character, are known *in* the upper quartzite; so this may be one of these. I have not analysed the white striated felspar of the "Logan rock;" but the microscopic evidence points to its being *oligoclase*, and not albite. Or, again, the beds might be held to represent the incoming of the upper gneiss below the so-called upper limestone, as green flaggy beds of this gneiss are to be seen below the limestone at Rhie Knock.

The bog to the eastward of Ben Brachaid makes everything obscure.

Again, the precise inference to be drawn from the existence of the "upper limestone" here, cannot be spoken to; for, though it *appears* dolomitic, it has not been yet analysed; neither do we know if albitic felspar is the substance which, under the name of hornstone, has been enumerated as one of its members, or if that felspar is an ingredient of the upper gneiss of the neighbourhood. Until we have information on these points the question is altogether too speculative.

In the upper quartzite there are to be found, on the south slopes of Cnoc-an-drien, a series of igneous beds, certainly three, brought to surface by several folds, which have been heavily cut in upon by denudation.

These consist of a rock generally similar to what occurs in the lower quartzite, and in the dolomite; still they differ from each other to an extent sufficiently marked to enable us to identify and determine the position of the several beds of the quartzite which separate them.

The first of these beds is found at an altitude of 690 feet,—not many feet above the dolomite,—the last igneous bed of which it much resembles. The second is seen after a swamp is crossed; it is at an altitude of 700 feet. This bed differs from any in the lower quartzite, or in the dolomite, in containing fatty quartz, and in having a milk-white felspar, the crystals of which have a reddish fringe. It is a much paler coloured rock than the others. The third bed is dark green from excess of hornblende, and it seems also to have a hornblendic and not a felspathic paste.

The above three beds are, through repeated folding of the quartzite, brought to the surface more than once on the hill-slope. Their relative position is, moreover, not interfered with by two dykes of a very singular rock, or by several dykes of the albitic porphyry.

Of the igneous rocks of the upper quartzite, as seen elsewhere, I would note especially what is seen in the ascent of the stream which flows from the Col between Ben Harran and Coniveall. Between 400 and 450 feet of the central portion of the slope consists of alternate beds of the red albitic

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porphyry and of quartz. A bed of grey porphyry underlies the highest red porphyry bed; above this there is quartzite and two beds of an igneous rock which has some of the features of the "Logan rock." Quartzite again succeeds, and the highest beds of the series—seen on the N.W. slope of Coniveall,—consist of a soft green fissile schist, an igneous bed, and lastly, a second bed of the schist. The igneous bed here is so much altered by weathering that its present features should not be taken as evidence of much value, except as proving a difference from the beds at the bottom of the series, which protrude through the turf, through *resisting* decay.

This rock at present consists of a soft grey paste enclosing a pale green foliaceous diallagic mineral. The same rock is to be seen on the N.E. slopes of Ben More, on the same horizon.

It thus appears that there is a very characteristic igneous rock, *the Canisp porphyry*, in the *lower* quartzite;—and an equally characteristic rock, *the albitic porphyry*, in the *upper* quartzite. The first occurs in a single bed, but in such enormous quantity that Nicol speaks of a square mile. The second, though at no single spot equal in bulk, is more generally distributed, occurring in many beds,—in many dykes,—and is apparently eruptive.

Not a particle of the characteristic rock of the *lower* beds has been found in the *upper;* neither has any of that of the upper beds been found in the lower, though in some localities the one set is nearly vertically disposed over the other.

It remains for those who maintain that there is only *one* quartzite, and that it has been folded over by an inversion, to explain the above facts, so as to confirm, and not militate against, their view.

There is still a rock, up to the present held to be igneous, which falls to be noticed here. This is the so-called "quartz porphyry" of Cnoc-na-Strome, of Scoonan Beg, and of Sail-an-Roar. That of Cnoc-na-Strome being Murchison's "red porphyry of Loch Borrolan."

This rock usually has no quartz. When present it is not in imbedded crystals, but as a paste. The felspar is orthoclase;—it is muddy, structureless, and unsatisfactory under the microscope. Cunninghame mentions having observed in it well crystallised rhombic-dodecahedrons of *magnetite*.

The writer has great difficulty in accepting this as an igneous rock. The chief argument for such a view lies in the aid which it would afford in explanation of the turmoil which exists among the neighbouring rocks.

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Possibly also such a view might be held to account for the presence of the adjacent marble.

The ground between Cnoc-na-Strome and Cnoc Ledbeg is obscured by detritus, but the writer has entirely failed in finding any line of demarcation, or faulting, either there, or between this red rock and the green igneous (?) rock of the hill east of Ault-na-ghalgach, at the spot where the junction occurs. Nor can one be found between Scoonan More, which is "Logan rock," and the overlying Scoonan Beg, which is the "quartz porphyry". At both localities the one rock, if it does not pass into the other, at least succeeds to it without break. All along the summit of Cnoc-na-Strome there is a rude bedding which is quite consonant with such bedding as is to be seen in the "Logan rock" of Cnoc Ledbeg, which it overlies; and bedding, or a structure as closely resembling bedding as any which is to be seen in the "Logan rock," is admirably seen in Scoonan Beg with the same strike, but having an almost vertical dip. Moreover, one of the more westerly beds of the "Logan rock," which is intercalated with the quartzite on the north shore of Cama Loch, is only to be distinguished from this "porphyry" by the very sparing presence of hornblendic matter. This bed, of brownish-red colour, contains little or none of the so-called *epidosite*,—the distinctive ingredient of the "Logan rock."

If it be urged that such a mass of highly crystalline felspar is something altogether new in a metamorphic rock, it has to be replied—firstly—that it has never yet been settled that the "Logan rock" is metamorphic in the usual sense of the word; and, secondly, that portions of the green rock of Liath Bhad on Loch Glen Coul, consist of much purer and broader, flaked masses of orthoclase than any in Cnoc-na-Strome, in which orthoclase the quartz is arranged in a graphic form—vouching for a still more perfect plasticity.*

Again I have to note that at the bridge over the Ledbeg river, near Ledmore, the rock, which certainly appears to be that of the hill foot of Cnoc-na-Strome, is largely changed into an agalmatolite mass—quite indistinguishable from the appearance and condition of the "Logan rock" where it overlies the dolomite at Liath Bhad. If the Cnoc-na-Strome rock be igneous, I believe it has caught up and transfused itself into masses of the "Logan rock."

The study of this district will prepare those who enter upon it with unprejudiced minds for new and wider views as to metamorphism;

* Mr. Hudleston picked up in Glen Coul, from the surface of "Logan rock," a loose fragment, in which the graphic lettering was surpassed in largeness of character by that of only three localities in Scotland.

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and such views may be still more amply developed by including in the study the singular porphyry which occurs in the S.E. foot of Ben Bhrachaid.

Igneous Rocks of the Upper Gneiss.

All the larger masses of this are of the fine grained white or grey syenitic type. They occur at Ben Loyal, Ben Stomino, and in the low district lying east of Lairg.

The rock is very fine grained, the hornblende is small in amount, and nearly an equal quantity of black mica is frequently present. *Sphenes* are far from frequent, and I did not see on Ben Loyal any clearly defined crystals. They are there very small, light hair brown in colour, and of the simpler forms. I could find no *Allanite*.

The rock of Loyal is disposed in great tabular sheets, with but few joints at right-angles. As this is one of the most gracefully contoured hills in Scotland, it may not be well to more than hint at the wealth of building material, finer than Aberdeen granite, which lies here. An opening in the corries south-west of Ribigill would, however, appear no larger than the scalp of a mountain torrent.

Cunninghame mentions *psilomelane* as occurring loose on the surface, between the summit of the north cliff and The Castles,—the top of the hill.

Upon the eastern slope of Ben Bhreck—a hill formed of Old Red Conglomerate, which lies south-east of Tongue—two large syenite boulders, probably from the crags of Loyal, are imbedded in till.

These were partly cut up for lintels, and fragments of what was designated "a pretty green stone," which came out of one of them, found their way into Dr. Joass' hands. This at once led to an examination, and ultimately to the larger part of the boulder being broken up by the writer in the interests of science.

I regard this as mineralogically the most wonderful and interesting stone in Scotland.

It was not only in itself a perfect mineral casket, containing in its small bulk as many minerals as do some counties, but it contained these in numerous crystalline forms, and also in crystals of large dimensions. It contained minerals found no where else in Scotland, and one which is altogether new to science. It offered ample scope for the speculations of the theoretical crystallographer, supplied abundance of material for the labours of the analyst, and, as it can hardly be ever proved to demonstration whence it came, it may always be turned to as an admirable

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bone of contention for those who prefer an evening's wordy war to a day's hammer-work upon a hill-side.

The boulder weighed originally about 100 tons; it is of the same rock as Ben Loyal. An exfiltrative granitic vein of about two feet in width passed through it; in or close to this, the minerals were found. These, arranged in the order of their occurrence from the substance of the stone to the centre of the vein, were:—

Babingtonite.	Ilmenite.
Fluor.	Amazonstone.
Sphene.	Oligoclase ?
Allanite.	Quartz.
Orangite and Thorite.	Specular Iron.
Magnetite.	Strontianite.
Lepidomelane.	Bhreckite.
Radiated Cleavelandite.	

And a substance of a somewhat doubtful nature.

It has been said that it is an exfiltrative vein; the crystals grow from both sides; the structure of the rock merges into that of the vein by a gradual incrementation of its parts; and the minerals appear in particles of increased size as they approach to, or incorporate themselves in, the vein structure.

The *Babingtonite* first appears in specks in the syenite itself; it seems to replace the hornblende. Near to, and at the junction of the fine grained rock with the coarse crystalline vein, it assumed the form of rough crystals, which were an inch or two in length, and increased much in width at their inner extremities.

The outer portions of the crystals were for the most part rough, somewhat incoherent, and penetrated by minute crystals of *lepidomelane, sphene* and *fluorite*.

The interiors of the crystalline masses were generally much flawed, but quite fresh. They had a vitreous lustre; a dark green colour; and they were both hard and tough.

No definite crystals were formed, but the summits always pointed to the centre of the vein. The specific gravity was 3·3.

The substance yielded—

Silica	50·845
Alumina	1·402
Ferric Oxide	9·56
Carried Forward	61·807

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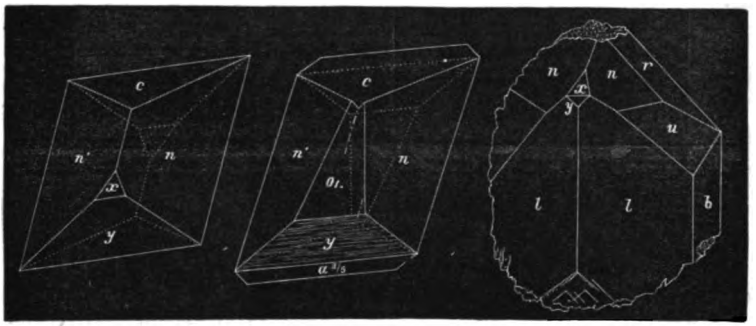
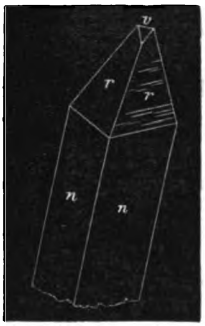
Brought Forward	61·807
Ferrous Oxide	8·807
Manganous Oxide	1·153
Lime	17·661
Magnesia	5·588
Potash	1·072
Soda	2·914
Water	1·485
	99·987 (H.)

Before analysis, it was taken to be *pinite*.

The *fluorite* is rare; it is of a pale purple colour, is in small fissured masses with a rude attempt at an octohedral form.



The *sphenes* are of a dark brown colour. The first three crystals figured were imbedded in brown orthoclase; the fourth projected into an open cavity of the same.



It was sometimes also imbedded in *Cleavelandite* and *Babingtonite*.

It yielded—

Silica*	35·5
Titanic Acid	30·4
Alumina	2·586
Ferric Oxide	4·914
Manganous Oxide	·4
Lime	26·423
	100·232 (H.)

The *Allanite* was also imbedded in brown orthoclase. No regular

* Since the silica of this sphene, as obtained from the bisulphate fusion, was not quite white when heated, it was re-fused; but it yielded no more titanic acid.

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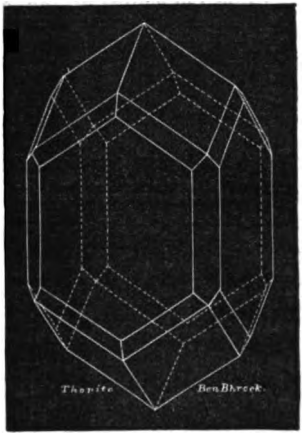
forms were seen, only single faces. It was in crystals about the size of the "lead" of a pencil; the usual yellow stain in the rock, and the jetty black lustre, were unmistakeable.

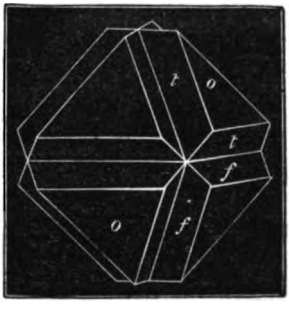
The *thorite* occurs in numerous round lustrous particles of the size of large shot. Pieces larger than a bean, however, occur; these are of a rich brown colour and very high lustre, except towards the outside of the particles, where they are sometimes dull and lighter in colour.

The centres of the larger pieces are sometimes light yellow *orangite*; there being a gradual passage into this colour through a rich brownish red. Some pieces, however, consist of *orangite* throughout.

Two small perfect crystals were obtained of the form figured. These are set down as *thorite* from their want of lustre, their opacity, their light brown colour, and want of hardness. Groups of larger attached crystals were also found. These were without the truncations of the edges. When broken they showed conchoidal fracture, a rich brown colour, and a brilliant vitreous lustre.



The *magnetite* occurs about the same zone, imbedded in felspar, in nodules of the size of peas and beans. It rarely shows octohedral faces; one twin tetrakis-octohedron was obtained.*



This magnetite is of a blue-black colour, and a high lustre. The powder is reddish-brown, and is strongly magnetic.

* In the figure the faces marked *f* should be *t*.

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It yielded—

Ferric Oxide	83·482
Ferrous Oxide	12·682
Manganous Oxide	1·200
Silica...	1·200
Alumina	·233
Lime...	·896
Magnesia	·500
	100·148 (H.)

From the centre of the crystals of this magnetite there were obtained some minute laminable specks of a magnetic substance which dissolves without residue in chlorhydric acid; and which precipitates an acidified solution of copper sulphate. Hence these must be *metallic iron*.

The *lepidomelane* occurs in plates, one or two inches in size, of a deep rich brown colour. These are imbedded in crystals of amazonstone, and they also separate crystals of the latter from flesh-coloured felspar. They are easily cleavable, but are, even in thin plates, nearly opaque. The mineral is not so tough as the Haughtonite of granites. It is slightly biaxial, and transmits light of a brown colour. Its specific gravity is 2·965.

It yielded—

Silica	40·076
Alumina	12·408
Ferric Oxide	18·474
Ferrous Oxide	2·668
Manganous Oxide	·615
Lime...	1·076
Magnesia	14·661
Potash	7·570
Soda	2·158
Water	5·298
	99·994 (H.)

This and the specimens from Achadhaphriz, are the only dark micas which I have, by analysis, proved to be lepidomelane in Scotland.

The radiated *Cleavelandite* occurs in considerable quantity. It marks the zone of the appearance of the *green* orthoclase; there being much

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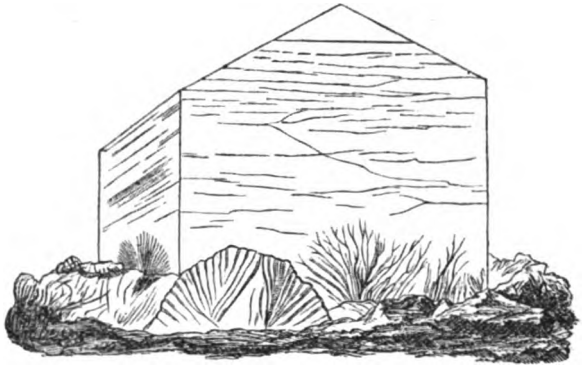
flesh-coloured orthoclase outside of it. It forms a curving belt of over half an inch to an inch in thickness; this belt being formed of lamellar



crystals which diverge as they become imbedded in the crystals of Amazon-stone. On the surface of the crystals, or in section, the Cleavelandite resembles a radiated zeolite, with a sheafy structure, the sheaves being occasionally isolated. The plates are white or colourless, and lustrous,—the lustre being pearly on the flat faces, vitreous on the edges: they are not much thicker than paper. Occasionally they radiate into quartz. The specific gravity is 2·622.

It yielded—

Silica	67·789	
Alumina	18·764	
Ferric Oxide	1·428	
Manganous Oxide	·076	
Lime	·516	
Potash	·757	
Soda	10·492	
Water	·159	
	99·981	(H.)

The *ilmenite* occurred in very small quantity, in thin blue-black plates, which lay between crystals of orthoclase, and also among the plates of the Cleavelandite. It was very much more readily powdered than is usual with this mineral.

The powder was reddish or brownish, and not blue-black as is usual.

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It yielded—

Titanic Acid	50·646
Ferric Oxide	9·878
Ferrous Oxide	17·784
Manganous Oxide	5·172
Lime	8·187
Magnesia	11·637
Silica	1·724
	99·978 (H.)

Of many ilmenites which I have analysed from various parts of Scotland this is very much the richest in titanic acid.

Orthoclase has been stated to be the matrix of several of the minerals which occur towards the outer portions of the vein. That orthoclase has the somewhat muddy flesh-colour which is so usual in the mineral. As it passes towards the centre of the vein it becomes clearer in colour, being somewhat like that of veal; and there are seen, in association with the magnetite, some crystals of a fine amazon tint. In this situation they are of about half an inch in size, and of simple forms.

It is a noticeable fact that of the orthoclase in this mass it is only the *amazonstone* variety which occurs in regular crystals; the flesh-coloured portions are crystalline, but not in definite forms.

These small crystals of amazon-stone first noticed occur imbedded in crystalline flesh-coloured orthoclase; and as we pass towards the centre of the vein, where the larger crystals commence to grow inward to its medial line, it is found that the roots of these crystals have the usual flesh-colour, while their summits or terminal portions have the amazon-stone tint, there being a gradual shading off of the one colour into the other.

It has also to be noted that while there is no indefinite, *i.e.* porphyritic arrangement in the *position* of the crystals, yet (as in the case of the albite of the Ben Brachaid porphyry) the *whole* of the orthoclase is not in defined crystals. Some, indeed a considerable portion of it, forms only a confusedly crystalline padding to the amazonic portion. That portion had become possessed of more and more intense power of polar arrangement as it increased in purity;—and this increase of purity took place as it approached the centre of the vein. Even here there are but few free summits or even faces; the vein has been almost totally plugged, and

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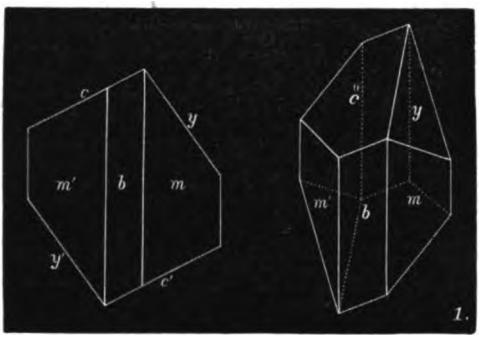
the amazonstone crystals are enveloped, even as regards their centrally-directed terminations, in quartz or in flesh-coloured felspar.

The *amazonstone* occurs in so many forms that the various crystallizations of the mineral might, to a great extent, be studied in this one stone.

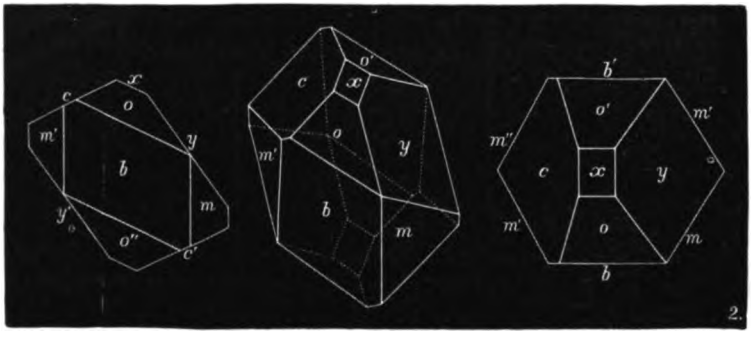
Two distinct types present themselves,—the *ordinary type*, or that in which there is no dominant growth along any axis; and the *clinodiagonal type*, with dominant growth along that axis.

The first type *only* occurs in the small crystals which are found imbedded at some distance from the centre of the vein. The second type is markedly the dominant one among the large crystals lying in the vein centre.

Among the small *exterior* crystals some have so few faces, while others have certain faces *so largely developed*, that the forms are difficultly recognisable; figure 1 is an instance of the first.



In figure 2 the dominance of faces *y*, *b*, and *c* is marked;



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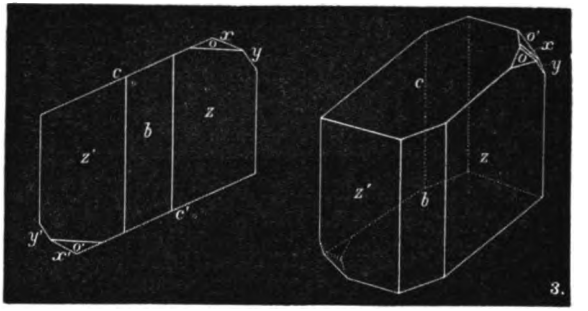
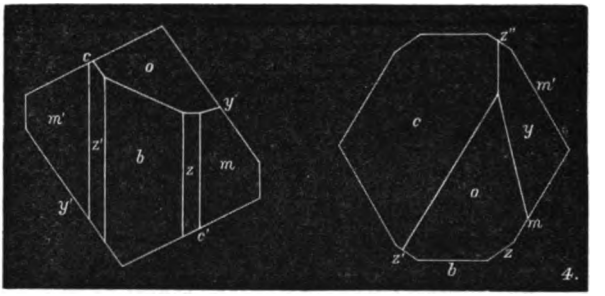
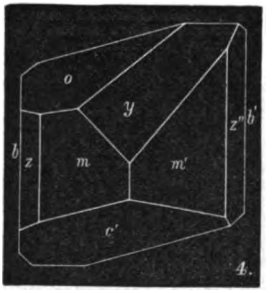
while in figure 3 the dominance of *c* and *z* is equally remarkable.



In figure 4 the hemihedrism of the face *o*, though not producing marked



distortion when looked at in plan (as in its first presentation), does so when the crystal is regarded either when the summit is looked at, or in the line of the clino-diagonal.



The analysis of the mineral was made upon fragments sent to me by Prof. Nicol and Dr. Joass, shortly after the discovery of the stone in 1875.

Its specific gravity is 2·569; its cleavage angle, 89° 43′.

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It yielded—

Silica	64·204
Alumina	18·395
Ferric Oxide	·455
Protoxide of Manganese	·152
Lime...	·725
Magnesia	·076
Potash	12·752
Soda	2·952
Water	·512
	100·223 (H.)

Copper, chromium, and nickel were specially sought for, but no trace found, nor was there a trace of ferrous oxide.

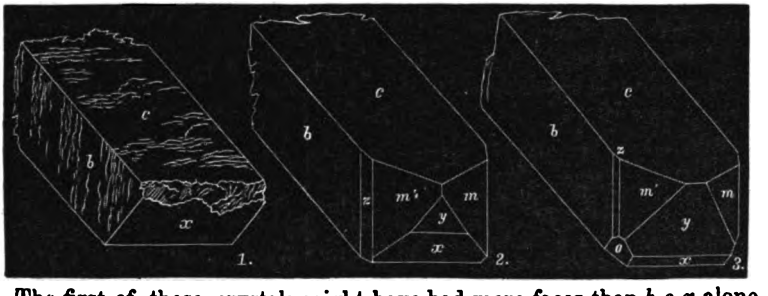
Many of the crystals are of so fine a colour that, when first seen, the effect, merely as a coloured stone sticking out of the side of a hill, was quite startling. From the centre of this mass, specimens of unparalleled magnificence were obtained.

Plate V. gives portraits of some of the crystals,—by no means the finest. Those figured varied from 8 to 18 lbs. in weight. Two crystals, which were un-terminated prisms, and which were unavoidably broken in the extraction, had the following very unusual dimensions :—

	Length along *b* and *c*.	Breadth over *b*.	Breadth over *c*.
1st	15½ inches	10 inches	8 inches
2nd...	12½ ,,	8 ,,	6 ,,

A magnificent museum specimen, now in the possession of His Grace the Duke of Sutherland, shows, on a surface of some three square feet, eight perfect and several imperfect crystals, of the size of the fist.

The crystals from the vein itself belong, as I have said, almost entirely to the *second* type.



The first of these crystals might have had more faces than *b c x* alone, as the fracture may have carried off *z m* or *y*.

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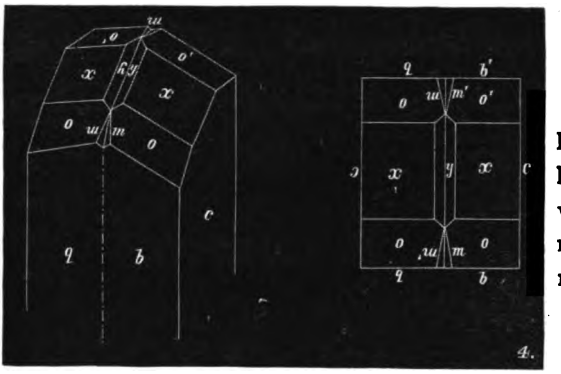


Simple crystals are however here rare; hemitrope forms prevailing, the axis of revolution being normal to *c*.

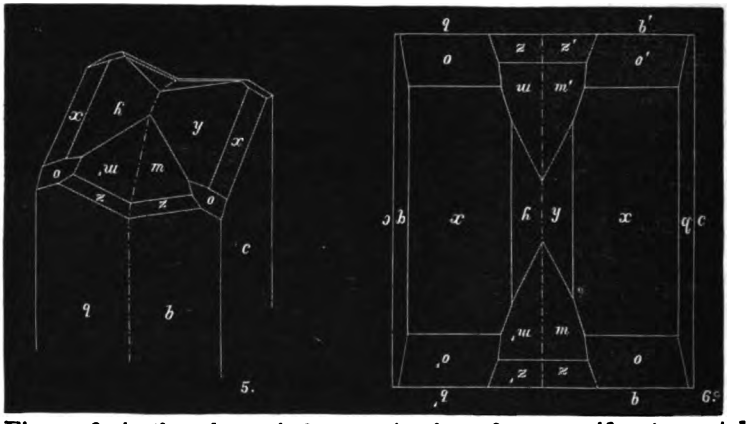
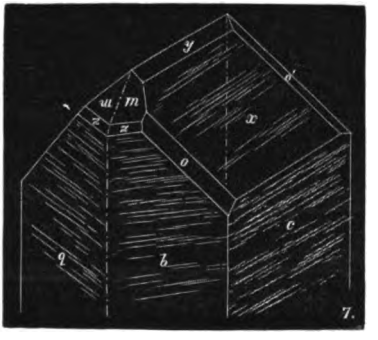


Figure 6 is the plan of the termination of a magnificent crystal, quite as perfect as drawn; this lies upon the surface of the large specimen which is in Dunrobin Castle.

These hemitropes are most frequently either hemimorphic or hemihedral. Figure 7 is hemimorphic, as regards the faces *o* and *y*.



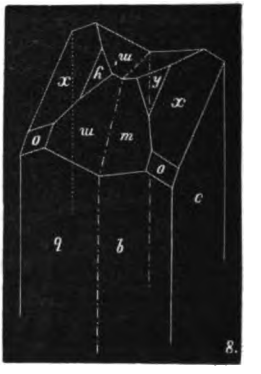


Figure 8 is *alternately* hemihedral, as regards the face *o*.

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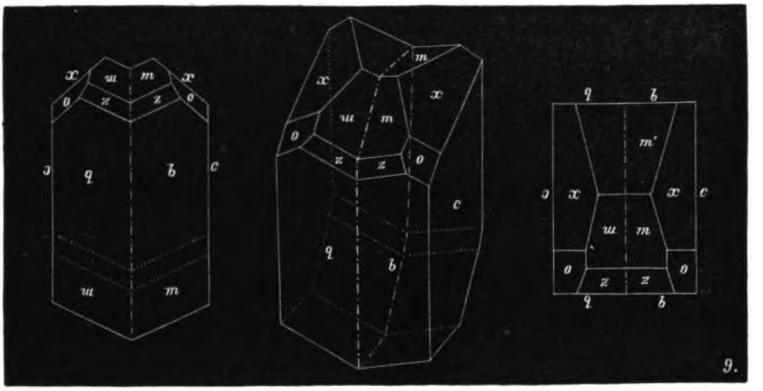
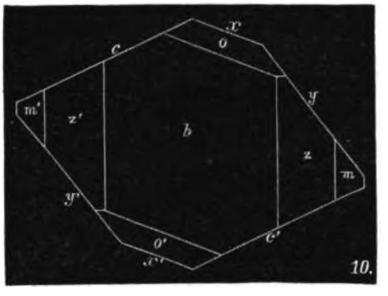
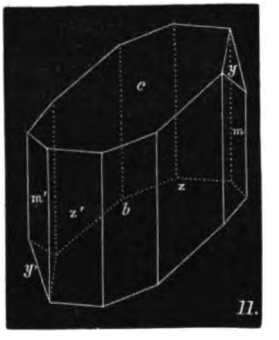
While figure 9 is so also as regards the faces *z* and *o*.



Of the forms belonging to the *first type* which occur here, figure 10 shows great dominance of faces *b*, *c*, *y*.

Figure 11 a still greater dominance of face *c*.





12 is a very unusual development.

13 represents the only specimen found here of this most common of all the forms of orthoclase.

I found one hemitrope of this last figure with the axis of revolution vertical, and with planes *x* and *c* nearly coinciding. A nacreous flash, which is reflected from *x*, but is absent from *c*, also shows that the revolution is a vertical one. The one portion of the hemitrope is much smaller than the other, and there is a peculiar dovetailing of the halves which will be noted below.

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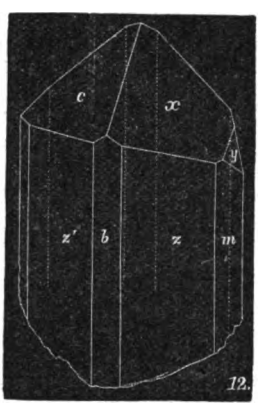
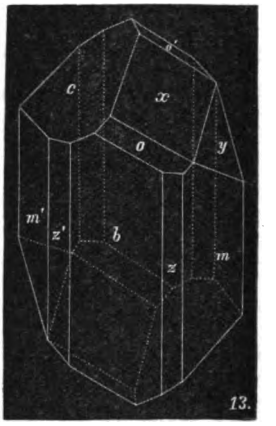
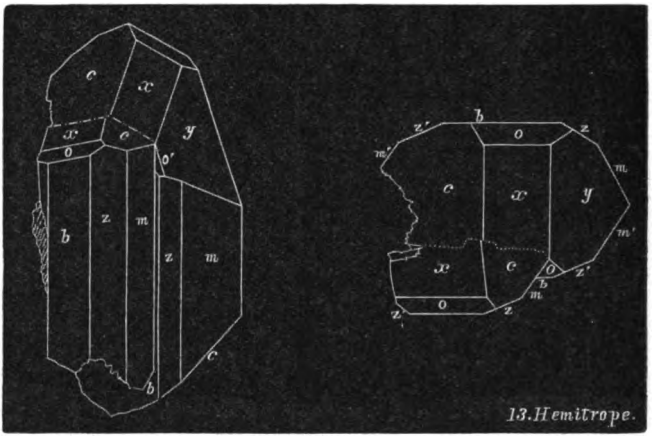


12.



13.



13. Hemitrope.

The next figure, 14, is a hemitrope of the same form, arranged in accordance with the same law; but here the revolved portion is not only much smaller, but is *inserted* into the bulkier portion, which latter is somewhat distorted, from unequal development of its faces *z*.

All the hemitropes of the second type are readily separated along the face of composition. When they have been separated, it is found that the two portions had been held together, first, by a mutual interpenetration or dovetailing, which is well seen in figure 6 of the plate (this figure was drawn by my lamented friend, Professor Nicol); and secondly, through a structure which becomes at once evident to the eye, upon the surfaces of both halves of the crystal.

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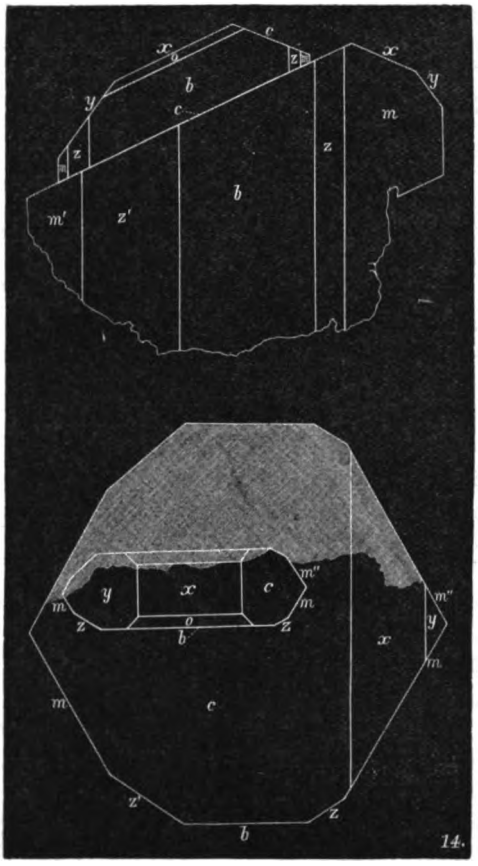

This peculiar structure I had observed many years ago in the *orthoclase* of Rubislaw quarry, near Aberdeen; I had noted afterwards that it was very generally if not always to be seen in the felspar of veins or dykes, especially of exfiltrative veins. It sometimes occurs in large, sometimes in small development; but never having seen it so strikingly displayed as in the amazonstone of Tongue, I very specially examined it in this, and made the following observations thereon:—

When viewed only on the surface of an opaque crystal, the structure resembles, in its somewhat interrupted markings, a graphic delineation of the distant waves of the sea; or the light reflected upon a polished piece of fine-grained ivory, cut parallel to the length of the tusk. When viewed in a transparent crystal through a lens, it resembles the fibres, great and

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small, of a partially untwisted cord, spread loosely and more or less uniformly across the crystal—the direction being invariably parallel to the face *a* of Brooke and Miller (*ii.* of Dana).

Professor Nicol of Aberdeen, who quite independently observed the same thing in these crystals, writes me (12th Nov. 1875) as follows:—

"The most curious felspar I have seen is one from a boulder. It is a macle like those in p. iii. of my 'Elements,' but broken at the ends; it is about 8 inches long by 2 broad.* It consists of red and green layers running across the cleavage face, and down the side of *m*, approximately parallel to its edge, and at right angles to the plane of cleavage, almost like fibres of wood or muscle. The brown and green are not in twins, but mixed in irregular plates—the cleavage runs right across both. The layers look like fat and flesh fibres in a piece of well-mixed beef. These fibres are not quite continuous, but more or less interrupted or broken. They are thicker near the outside.

"You call it amazon-stone, but I think it is rather orthoclase, *mixed* with the green mineral. This is more gem-like and less altered than the red. I am inclined to think also harder."

Up to the time of receiving Professor Nicol's letter I was uncertain whether these markings were to be regarded as due to a peculiarity of structure, or to an actual difference in material; though I inclined to the latter belief from having observed the fact, noted above by Professor Nicol, that the fibrous-like substance invariably weathered faster than the general mass of the crystal. The opinion of so acute an observer as Professor Nicol strengthened me in this belief; but it was not until I had analysed many such felspars, and more minutely examined the structure, that I definitely came to the conclusion that Nicol's view as to their being *actually two chemically different substances conjoined in one crystal* was the correct one.

The observations I have made, so far as yet carried out, are the following:—

1. *The Structural Appearances.*

These fibres and fibrillæ invariably differ in colour, lustre, and transparency from the general substance of the crystal through which they are spread. When viewed perpendicularly to the face *c*,—that of most perfect cleavage,—they frequently appear opaque, white, or brownish-red, always lighter in colour than the general mass of the crystal; but this opacity is,

* This crystal had been sent to him by Dr. Jeass.

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except in the case of weathered crystals, the result of the manner in which the light is reflected from them.

Placing the crystal as usual, with the macro-diagonal transverse to the observer, and reflecting light from the general surface of the face *c*, the striæ pass as dull or opaque white interrupted lines from the observer, the face itself frequently exhibiting a faint lineation between the fibres, parallel to the macro-diagonal; but on revolving the crystal upon the diagonal about 4° either to, or from, the observer, the corded structure starts out with a nacreous glimmer, somewhat similar to that in *sonnenstein*; the edge between the two reflecting faces lies parallel to the macro-diagonal of the large crystal, and the light appears under the lens to be reflected from innumerable interrupted cleavages.

When the somewhat imperfect *a* cleavage is obtained, a less interrupted and somewhat more brilliant flash is thrown from spots upon its surface; —careful observation being required before the impression is done away with, that the light is reflected from thin plates of talc.

In the more brilliantly green-tinted and transparent amazon-stones, the colour of these so-called fibres is usually of an opaque white; in some duller crystals they have precisely the tint of dead muscle. It has also to be noted that they are quite as largely developed in those portions of the crystals which are flesh coloured, as in the green; though from the contrast of colour not being so marked, they are not there so readily observable.

2. *Is the Material of the duller Portions different from that of the general Mass?*

In no specimen that I have seen is it within the bounds of possibility to separate the one from the other, so as to determine this by actual analysis;* but it may reasonably be concluded that they are different, on account of (1st) the higher lustre of the filamentous portions when unweathered; (2nd) the greater rapidity with which these portions do weather; (3rd) their greater opacity when weathered; (4th) their inferior hardness,—for a soft knife drawn across both does not scratch the general mass, but only the fibrous portions.

3. *What proportion of the Crystal does this intruded or extruded material bear to the ordinary Orthoclastic Substance?*

The habit of taking the specific gravity of all minerals analysed, led to my being able to form a fairly approximate estimate of this.

* Quite recently, I have been able to knock off so much of the white skin (which appears to ramify as this structure in the crystals) as enables me to say that it is a soda-lime felspar. Feb. 1883.

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Many determinations of specific gravities of orthoclase from diverse localities give an average of 2·555.

A crystal of the variety called Murchisonite, obtained at Loch Ransa, on Arran, gave the exceptionally low specific gravity of 2·3 ;—the weight if the crystal was 163·3 grains in air; 92·3 in water :

$$163{\cdot}3 - 92{\cdot}3 = 71;\ \tfrac{163{\cdot}3}{71} = 2{\cdot}3.$$

It was boiled, when it gave out much air from lines transverse to the face *c* ; it was now cooled under water, dried with blotting paper, and re-weighed in air and in water. It now weighed in air 169·5 grains, and in water 98·3 grains,—the buoyant effect of the air previously in the pores being done away with.

$$169{\cdot}3 - 98{\cdot}3 = 65:\ \tfrac{169{\cdot}3}{65} = 2{\cdot}512,$$

which is, therefore, the true specific gravity of the solid matter of this crystal.

But the weight of the crystal in air with its pores filled with air was 163·3 grains; and with its pores filled with water, was 169·5 grains ; the weight of a bulk of water equal to its pores is therefore 6·2 grains ; and as the substance has a specific gravity of 2·512, the bulk of its pores in its own material would weigh $6{\cdot}2 \times 2{\cdot}512 = 15{\cdot}57$ grains. This, added to its original weight, so as to get the weight which the crystal would have been if solid, gives $163{\cdot}3 + 15{\cdot}57 = 178{\cdot}87$ grains; the weight of the bulk of the pores was 15·57,—and $178{\cdot}87 \div 15{\cdot}57 = 11{\cdot}487$.

So that these pores are about one-eleventh and a half, $\frac{1}{11{\cdot}5}$, of the total bulk of the solid.

The relation between these pores in Murchisonite and the subject under consideration is now to be shown.

Murchisonite is chemically an orthoclase, but it is characterised by an extra cleavage—(not seen, so far as I know, in Scotch specimens), and by a peculiar pearly glimmer when viewed in certain positions. An examination into the cause of this optical peculiarity seemed to show that it was due to a structure identical with that above described as occurring in the amazon-stone,—only that vacuities took the place of the material constituting the fibrous net-work.

The crystal I was examining, however, being a complex twin of eight individuals, was ill adapted for the display of internal structure ; and I was fortunate in having in my hands a simple and well-developed crystal which Mr. Dudgeon had sent me to figure.

I was not, of course, able to get a section of it, but an examination by the lens at once and unmistakeably showed that the characteristic lustre was due to internal reflection from a multitude of flattened microscopic

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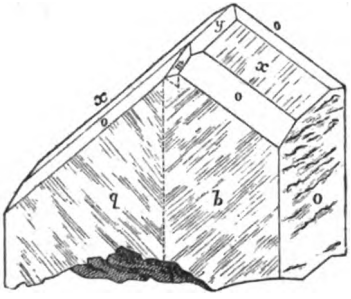
pores, arranged accordant with the axis of the crystal, parallel to the face *a*.

So far as the power of the lens went, the pores seemed similar to those of *hypersthene* (Paulite).

The structure, therefore, is identical with that under consideration, only that in Murchisonite it is porous, or empty.



Hemitrope of orthoclase from the Hill of Fare.

A crystal lent me by Professor Nicol actually showed this identity. This crystal was a hemitrope of the form depicted; it was got in a quarry at Upper Craigton, Hill of Fare, Aberdeenshire. The general colour of this hemitrope is a reddish brown; the faces *b* which are smooth and somewhat transparent, show the fibrous structure, shining up from the depths of the crystal on account of the relative lightness of its colour. The face *c*, again, shows a lineation through deficiency of substance; consisting of a transverse series of pitted markings, which are the openings of the pores.

A point of considerable interest in this crystal is that the portion covered by the face *m* is either of a purer or of a different nature from that of the general mass. It forms a small wedge of nearly colourless and transparent material *let in* to the general substance.

The weight of this crystal in air was 48·28 grains; in water, 27·12.

$$48{\cdot}28 - 27{\cdot}12 = 21{\cdot}16,$$

$$48{\cdot}28 \div 21{\cdot}16 = 2{\cdot}282,$$

which is the specific gravity with pores *air-filled*.

Boiled in water, air escaped from the pitted markings; after cooling in water and drying it weighed 50·13 grains in air, and 29·13 in water.

$$48{\cdot}28 - 29{\cdot}13 = 19{\cdot}15,$$

$$48{\cdot}28 \div 19{\cdot}15 = 2{\cdot}521,$$

which is thus the true specific gravity.

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But the water weight of the pores is equal to the difference between 48·28 (its weight with these pores air-filled), and 50·13 (its weight with pores water-filled),=1·85.

And $1{\cdot}85 \times 2{\cdot}521 = 4{\cdot}66$,—the weight of the bulk of the pores if they were solid.

This 4·66 added to the original weight of the crystal, 48·28, gives 52·94 as what would have been the weight of the crystal if it had been solid; and $52{\cdot}94 \div 4{\cdot}66$ gives 11·36.

So that in this crystal the amount of the foreign matter now represented by pores is about one-eleventh and a third, $\frac{1}{11}\cdot\frac{1}{3}$, of the whole crystal. A remarkable coincidence with the proportions in the Arran crystal.

I find that many crystals of orthoclase exhibit these vacuities in their substance, exactly corresponding in position to that of the structure which has been described. Crystals of adularia from St. Gothard are frequently hatched, and cross-hatched in twins, through the lineation produced by this deficiency of substance. I possess a crystal which is little better than a skeleton from this cause.

4. *What is the Material of which this Knitted Structure is composed?*

It would not, as before mentioned, be practicable to separate the material from the orthoclastic mass: by a consideration, however, of the composition of those felspars which exhibit the structure, a conclusion, which it would not be unreasonable to consider as closely approximate to the truth, may be drawn.

The analyses of such felspars show so slight a departure from the average analyses of orthoclase, that the substance evidently cannot be very far removed from orthoclase in composition. The only decidedly noticeable differences are an excess of soda over that normal to orthoclase, and the introduction of some lime.

The first point here to be noted is that as the amount of silica is quite normal, and as the substance of the lineation is the softer part of the structure of the crystal, it cannot consist of quartz. Had this been the case its occurrence in the position occupied would not have been altogether inexplicable, for then it would have consisted of the excess of silica over and above that necessary to saturate the bases in the formation of felspar; which excess, indeed, the quartz in granite veins must probably all be regarded as representing. Such an excess of silica, *and so separating*, forms in the graphic felspar of Ben Capval and Stromay, in Harris, a structure wondrously similar to that under consideration.

The *sonnenstein* appearance of the layers gives rise at once to a suspicion of their being composed of some species of felspar; but how a

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felspathic material should, in thus being extruded from another of similar nature, form so strange a structure, instead of regular crystals, is the roblem to be solved.

Now, seeing that other felspars are paragenetic with orthoclase in veins, that they are softer, and, with the exception of albite, more readily decomposed, it is very probable that the material consists of one or other of these.

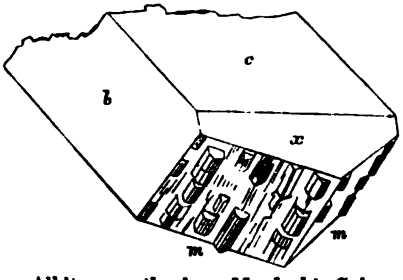
There are, however, judging from geognostic relationships afterwards to be pointed out, only two that it can well be,—albite and oligoclase,—and the evidence appears to be rather in favour of its being the latter.

An admixture of oligoclase with the orthoclase would introduce both soda and lime,—albite would only bring in the former, and that only at the cost of simultaneously increasing the quantity of the silica, which oligoclase would not do.

As regards association, oligoclase very frequently accompanies orthoclase in granite, especially in veins. Again, albite is exceedingly rare in Scotland in granite. I only know it at Stirling Hill, and Murdoch's Cairn quarries, near Peterhead, and in smaller quantity in the quarry of Craigton, Hill of Fare; moreover at these localities it does not occur in veins, but in druses in the granitic mass.

Albite, moreover, it is well known, weathers less rapidly than orthoclase (except perhaps in the rare case of its occurring in trappean rocks); but the material of these laminæ, or whatever they be termed, weathers decidedly more rapidly.

And lastly, albite is not paragenetic in time with orthoclase,—the latter is always proterogenetic to crystallised albite, the crystals of which are generally disposed on the top of the former. Indeed, in Murdoch's Cairn the albite is evidently a product of a change in the orthoclase, being always disposed on apparently corroded *m* faces of the latter, the axes of the



Albite on orthoclase, Murdoch's Cairn.

crystals of both being accordant in direction. (See figure.) Oligoclase, on the other hand, is in all respects paragenetic with orthoclase,—at Lairg

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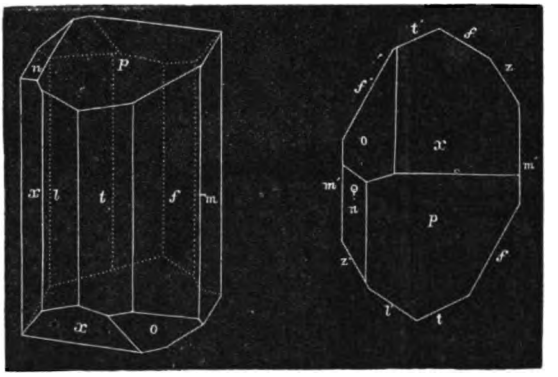
they are imbedded side by side in quartz; at Sclatty, Rubislaw, Craigie-Buckler, &c. they are mutually assertive, and mutually interpenetrating.

In the Tongue boulder, though ordinary albite does not occur, yet the sheafy Cleavelandite variety is somewhat rarely found; but this is here markedly proterogenetic to the amazon-stone. It thus forms a "basement mineral" to the crystals of the latter; and though a few crystals of what *may be* albite are disposed on the surfaces of crystals of orthoclase, its occurrence in two zones is most unusual.

It has to be stated, moreover,—whether it be an argument for or against the above view I know not,—that at several of its localities oligoclase does not occur *otherwise* than thus imbedded—that is, does not occur in separate crystals—indeed this is the case in those localities where this structure is best seen. The same thing, however, applies to albite, which does not occur in determinate crystals or masses at any of the localities where the structure has been observed, with the single exception of that of Stromay.

The evidence in favour of the material of the structure being *albite* is extremely weak. It consists merely in the fact of some minute crystals (which occur coating some of those of amazon-stone), being in the form



drawn. This form may be referred to *albite*; but, without angular measurements, they could not be set down definitely as albite, as the form is quite referable to *oligoclase*. Indeed, the black line figure is the form lately given by Naumann as *characteristic* of oligoclase; and this, it will be observed, is but a more complex form of the Sutherland crystal.

It has been stated that these minute crystals occur on, or coat the amazonstone. It will also be observed that in Professor Nicol's figure (see Plate V., fig. 1), he makes the quantity of the interstitial matter increase near the surfaces of the crystal. This is very often the case; sometimes the interstitial substance may be even seen to run in from an outer-coating

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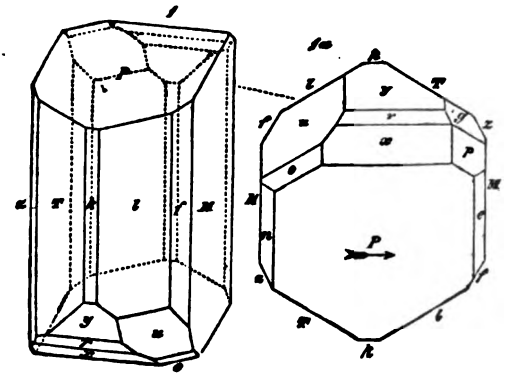
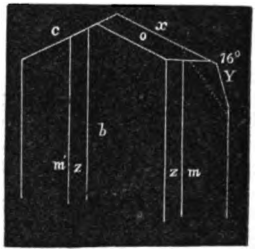


of white material. This white layer only occurs on certain faces. A most interesting illustration is the figure in the margin, where a crystal of the ordinary form has a quantity of the white matter *set on* to it, upon the face *y*. This small portion is rivetted to the general mass of the crystal by throwing processes into its bulk, and it is the ramification of these processes which produces the structure in question. The little tip of white material has on it a face more acute than *y* (Y), which forms with *x* an angle of about 76°.



It is here to be noted that there is in *Perthite* a somewhat parallel banding of *orthoclase* and *albite*. The two were in that mineral probably paragenetic in time; but the microscopic structure of *Perthite*,—the only variety of felspar in which there has been a chemical determination of the nature of the layers,—is so different from *this*, as to form the very strongest argument against the view that the intruded mineral is *here* albite.

A piece of special pleading in favour of admitting this structure to be formed of *albite* is, that by so doing the amazon-stone would be included under *microcline*. As the angular inclinations of all the crystals depart from a right angle, they *are* microclines whatever be the nature of the distorting substance.

This *departure from a right angle* has now to be considered.

5. *Has this intruded Foreign Matter any effect, and, if any, what, upon the inclosing Crystals?*

The cleavage angle of every one of the felspars showing this structure

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departed more or less from 90°; *and the departure from a right angle is greatest in the felspars which show the structure in its strongest development.*

Lairg, 89° 39′; Rubislaw, 89° 58′; Stromay and Ben Capval, 89° 50′; Tongue, 89° 45′; Cowhythe Head, 89° 40′; Blirydrine, 89° 40′; Eslie, 89° 40′; Anguston, 89° 49′; Yestnaby, 89° 56′, are a few quotations; these being, out of measurements of several fragments, those which were the most common. Though measurements nearer to 90° were occasionally obtained in such felspars as show this structure, none were absolutely at the right angle.

If we suppose that the foreign substance is oligoclase, and that the polar axes lie accordant with one another,—which it will be shown that they do,—the obliquity of the cleavage angle in that substance should more or less distort the orthoclastic cleavage.

The angle of oligoclase differs 230′ from that of orthoclase; the amount of oligoclase present seems about $\frac{1}{11}$; the eleventh part of 230′ is 21′.

The case of those crystals which, like the Murchisonite, are systematically porous, here calls for consideration. The crystal from Arran, being a complex twin, was unfitted for the determination of the angle.

If the open structure and the filled-up structure be in reality the same, and if the crystals now vacuous be also more or less triclinic, we must conclude that the oligoclastic material segregated out of the orthoclastic, when both were solidifying nearly contemporaneously; and that in the hollow crystals the more decomposable mineral had been weathered or dissolved out. All Murchisonites I have seen were either loose stream-rolled crystals, or they were weathered; but it was not so with the Hill of Fare specimen; it was taken from a freshly-opened cavity.

It cannot be supposed that the crystalline molecules of the orthoclase arranged themselves preconcertedly, so as to distort the crystal; and also so as to leave vacuities for the reception of *a pre-selected* substance. The action of the crystallipolar force, in its wondrous production of hemitrope, twin, hemihedral, and hemimorphic crystals, must be said to be *determinative*, but we cannot assign to it the function of being *deliberative*. And though it is quite conceivable that pre-existent vacuities might be plugged up by the accretion of a subsequently solidifying felspathic material, or, in its absence, of the siliceous paste, still it is inconceivable that vacuities—the *absence* of material—could distort the angle of a

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crystal. "Nothing can come of nothing." An insufficiency of accreting molecules sometimes produces modifications—new faces on a crystal,—but is powerless to alter its angles; and we are thus forced to conclude, as above, that the contemporaneous, or nearly contemporaneous solidification of the triclinic substance within the orthoclastic, distorted it laterally; and that the open structure in all felspars in which the angle departs from 90° is, in a double sense, an *outcome*,—due to the removal of a material soluble in a solvent which is incapable of attacking the orthoclase.

I have somewhat particularly described this structure, as I have known it to be mistaken for that striation which is insisted on by some geologists as a reliable criterion in the discrimination between orthoclase and the plagioclastic felspars;—the following distinctions may, however, be pointed out:—

The structure differs from the striation of twinning in that its markings are not rectilinearly parallel, but occur in undulating lines,—more undulating in *c* than in *b*; they *cross* the face *c*, being at right angles to the macro-diagonal, while the lineation of repeated twinning is parallel to the macro-diagonal; they are not alternately lustrous with the other parts of the crystal, on revolution upon an axis parallel to their own strike; they are coalescent; and they are lighter in colour than the rest of the crystal.

I might add that, as these markings are as frequently seen in these vein orthoclases as striation is in the plagioclastic felspars, they are as good a mode of discrimination between the two as is the latter; and, as they have never been seen in a plagioclastic felspar, while striation may occasionally be seen in *every* plagioclastic felspar, they give, where seen, some absolutely *specific* information, which striation can never do.

As the hemitropism of the crystals of amazon-stone exhibits this singular structure in a modified development, it calls for notice.

This amazon-stone, as before noticed, is frequently in hemitrope crystals which are pervaded throughout with the corded structure, and that to such an extent that the white opaque filamentous matter acts as tenons to the two halves of the hemitrope, binding them together, until separated by force; then the white substance is seen with fractured edges like the separated sutures of the disconnected bones of a skull.

The faces of the separated halves of the hemitrope are found to be highly polished and lustrous; the white ruptured lines passing across them in relief or depression according to where the fracture operated,—like the rugosities of a single-struck file.

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On pressing the two halves together, a certain amount of cohesion is re-established, as in the forcible reinsinuation of the sutures of the bones of the skull.

Difficult as it is to account for the arrangement of the molecules during the reversed polarity which is operating whilst a twin or hemitrope crystal is being built up, there is here something more difficult still: for, across the path of the molecules of the green matter, while moving towards their appointed positions, there must simultaneously have been moving those other white molecules, engaged in their work of building up an inosculatory net-work; a system of net-works rather, extending not like the float of the fisherman in single line, but in innumerable parallel dispositions, stretched with perfect verticality * across the crystal, as the net of the fisherman is stretched by its leads with perfect verticality in a tranquil sea. But a consideration of what must be the relative motions of the molecules which are going to form a hemitrope crystal, would necessitate our comparing their influence upon the white layers in such crystals to that of a flood-tide impelling the buoy-rope and also the lead-line of a net the one way, while a medial current of ebb swept its corded structure in the opposite. In accordance with this,—at the face of revolution of the two halves of the hemitrope, the line of direction of this multitudinous net-work abruptly bends, and in its altered course maintains, as before, a perfect parallelism to the face *a* of the revolved segment of the crystal.†

It is this lineation, parallel to the face *a*, which, in a hemitrope thus formed,—*i.e.* by revolution on an axis normal to *c*,—produces the "herring-bone structure" seen in the orthoclase of rock sections; and not, as has been stated, one which is "characteristic of macles of the Carlsbad form."

This lineation, which strikes across *c* at right angles to the edge of *b*, could produce no angular lineation in a "Carlsbad twin" formed by its *first method*, namely by revolution *round an axis normal to b*; as the severed lines would again meet with the same strike. Neither could any herring-bone structure be formed by this lineation in a hemitrope or twin of the *second method*, namely where there is revolution of one half round a *vertical* axis; for the same rectilinear apposition would again result. There would have to be (which there is not) a lineation parallel to *o*, before a "herring-bone lineation" could be produced in either case; and

* Supposing the crystal to be placed as usual with the faces *m* vertical.

† See figure 3 of Plate V., also Hill of Fare crystal.

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even then it must perforce be a *hemimorphic lineation*, parallel to *two only* of the four *o* faces.

But this white substance, if oligoclase, must not be regarded as merely *extruded* from the green, in the manner that amorphous impurities would be.

As a definite chemical compound, it is itself subject to the operation of the crystallising force, in its double function as a physical separater and a symmetrical arranger. It is so arranged here, and the law of the arrangement is a singular one. It has been stated above, that the white reticulated structure is generally parallel to the face *a*, and gives a glimmering cleavage reflection when revolved about 4°, either to or from the position of ordinary reflection of the face of the crystal as a whole. This glimmering reflection is unmistakeably from repeated cleavage faces, which give between each other an angle of about 9°. Such a cleavage angle is unknown in orthoclase; but the angle is as near that of the salient angle between the faces *p* of hemitropes of oligoclase, as reflections from so small surfaces could be expected to afford. Such hemitropes, however, are formed by the revolution of one-half of the crystal round an axis at right angles to the face *m*—that is, round the brachydiagonal—which, of course, is at right angles to the axis of revolution of the main crystal.

In fine, we have here a squat crystal of orthoclase,—squat as regards the length of the vertical axis,—which crystal is a hemitrope accordant with face *c*, laced throughout by thread-like hemitropes of oligoclase (?), the main axes of the two being accordant, but the axes of the hemitropism being at right angles to each other. We have molecular repulsion coexistent with a peaceful crystalline consorting in one and the same fabric, a consorting which, perhaps, is all the more firmly interwoven, that, as regards hemitropic arrangements, the substances uniting have agreed to differ. Perhaps only those who have studied the motions of the molecules which, in a fluent menstruum, are engaged in the building up of regular solids, can in any measure appreciate the intricate evolutions of the molecules of these two substances, as they evaded one another in finding each its alloted place.

I would propose the term *corded structure* for what has been described; and I adopt to the full Nicol's view, to which I would give the following detailed expression, that *two substances of a nature differing both in composition and in molecular segregation,—differing also unquestionably in the system of crystallization to which they belong,—have here harmoniously united in one structure, in which the rectilinear rigidity of crystalline arrangement is pervaded, but not infringed, by the flowing curvatures and*

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wavy lines of a structure as involved as the anastomosis of plant or animal life.

I must, however, refrain from proposing a name for the crystals which exhibit this structure, until their optical properties disclose whether the included substance is albite, or, as I suppose, *oligoclase:* should it prove to be albite, these are all, of course, *microclines*; should it be oligoclase, the crystals have the same claim as has that mineral to a specific name.

I have here to note that in the summer of 1876 a single mass of apparently a dark green felspar was broken out of a vein in Rubislaw quarry by Professor Nicol and myself; this upon examination was found to exhibit the structure very plainly. The felspars here proved to be not only orthoclase but also a striated oligoclase; and the included and colouring material proved upon analysis to be the new mineral to which I have given the name of *rubislite*: so that this singular structure may be impressed upon oligoclase as well as on orthoclase, and the plugging material is not necessarily a felspar.

The Structure as seen in the Microscope.

The structure which is visible to the eye, aided by the power of a lens, has, thus far, alone been considered; but when thin slices of the amazonstone are examined in the microscope, especially with the aid of polarised light, a still more intricate and wonderfully beautiful arrangement of the parts unfolds itself.

The lineation which has been mentioned as being faintly seen on *c* parallel to its edge but transverse to the corded structure, is now seen to be the result of the apposition of acutely wedge-shaped crystals. Two sets of these interlace with each other, like the teeth of two combs placed in apposition with forcible mutual insinuation.

With parallel Nicols, one set of these crystals—the teeth, as it were, of one of the combs—is highly coloured, the other being colourless, or polarising the complementary tint in feeble amount; but each individual crystal—each tooth of the comb—is transversely banded by stripes of complimentary colour; as if itself built up of myriad crystals,—a pile of numerous twins, the length of the individuals whereof diminishes gradually to the summit.

With crossed Nicols all this disappears from the lately coloured set, that which was previously colourless now assuming an identical appearance.

The twinning thus developed, being at right angles to the twin-face of the large crystal, and also at right angles to the supposed twin-face of the

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myriad individuals which build up the corded layers, produces therewith a structure of wonderful intricacy, and one which is altogether inexplicable by the known laws of the crystalline force.

The appearances, when examined by polarised light, of slices cut parallel to *c* and to *b*, are shown in the plate. (Plate VI.)

When the slice is examined without employing the analyser, the appearances go far to prove that two if not more felspars go to build up this comblike structure itself. This is disclosed first, by an opacity in some few of the teeth. The analyser immediately shows that these do not polarise at all, and their granular structure seems to show that they are decomposing. In marked contrast to the opacity of these, is the alternately greater pellucidity of the teeth, as thus seen.

The minute crystals which cross-bar the teeth are now seen to intersect several of them; at least they sometimes do so, tapering to both extremities. Others give a lozenge shaped section, indicating that they probably are oblique or anorthic. When the slice is in focus generally, these also seem somewhat opaque; but the throwing the slice slightly out of focus, shows them to be transparent,—the apparent opacity being due to a difference in their refractive powers.

The impression conveyed is, that these *cross-bar crystals* consist either of a third felspar, or of a different mineral.

No optical phenomenon whatever is developed in slices parallel to *a*; this goes so far in negativing the supposition of there being a twinning of crystals in the inclosed oligoclase.

This *comb-like* structure, above described and figured, is altogether different in its nature and appearance from the "rectangular-reticulation" which is to be seen in Aberdeen, Dalbeattie, and many other *mass-granites*, which do not show the "corded structure."

I have, indeed, seen but rare traces of the rectangular structure in association with the corded structure (with one exception, possibly); and where these traces were visible, the difference in the two structures was clearly defined. The rectangular structure is delineated, in continuous *lines* which are of *nearly* equal length and of equal width; in the rectangular directions those parallel to *a* are, however, neither so uniform in spacing nor so marked in tone as the other set. The cross-barring of the combed structure is delineated by *bars* of diverse colours, which are not continuous, either as regards their breadth or position, with those of the adjacent wedge-like crystalline shoot.

Where the corded structure is but feebly developed, the comb-like structure is still less so; it being then confined to the centres of the spaces

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which lie between the opened cords; and here the only cross-barring consists of a system of very flat transparent lens-like portions, which do not polarise. These also are very different from the dark bars of equal width of the "rectangular" structure.

Having sliced many portions of the amazon-stone, I have seen but two modifications of its peculiar structure. In one the *corded structure* was cross-barred, the general mass being plain. In the other a series of broad sygmoid-like undulations of diverse colours passed diagonally but intermittently across the spaces which lay between the cords.

The single locality in which I have seen an association of the corded and of the rectangular structure (there being no traces of the comb-like) is in the orthoclase from the great dyke opposite the rock of Stromay, in the Sound of Harris. And I have to add that, so far as my observations have gone, the felspar of graphic granite does not show the corded structure, but a rectangular one in which the lines parallel to *a* consist of a series of intermittent and irregularly disposed fissures. In this there is a marked approach to the structure of *Perthite*. *Perthite* consists of alternate layers of *orthoclase* and *albite;* the orthoclastic layers being reddened by the presence of innumerable crystals of *rubin-glimmer;* the albitic layers being white. The relative position of these plates in the compound crystal or mass is identical with that of the comb-like and also of the corded structures in the Sutherland amazonstone,—that is, disposed in plates parallel to *a*. Now, both the Canadian and the Scotch specimens of *Perthite* show a system of fissure-like markings, both in the red and in the white layers. Those in the red are very fine and numerous; and such are confined absolutely to these layers. They are not at all of the nature of rents, but more resemble strains. Those of the white, on the other hand, which are parallel to *c*, though not amounting to cleavages, from a want of continuity, *are* rents; and sometimes crack across and cut several of the red layers.

I have stated above that I had found in the quarry of Rubislaw, specimens of orthoclase in which the new mineral *rubislite* occupied the position of the oligoclase in the corded structure.

Lately I have had a slice made of a specimen, and I find that it contains, on one side, corded processes of *rubislite*, on the other of *oligoclase;* while at other parts the rubislite seems to *stain* the oligoclase. More than this, what seems to be *a rent* (it passes at right angles to the line of the corded structure) is filled with rubislite. This fact, taken along with the occurrence of rubislite in *both* felspars, and the occasional irregularity of the structure itself, certainly leaves room for the question if *all this*

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structure may not consist of a system of rents, which have afterwards been filled.

In the Rubislaw specimen the corded structure shows "cross-hatching" *in its own substance;* the principal lines of the cross-hatching being at right angles to the main direction of the "corded structure" itself.

Remaining minerals of the Amazonstone Vein.

The *quartz* which is present in this vein hardly appears till the centre of the vein is reached; small quantities only being seen imbedded in the felspar.

The roots of the larger amazonstone crystals contain it occasionally, arranged in a crudely graphic manner. Larger lumps of a brown colour, with paler portions which pass like cords through their centre, are also present here. These paler portions seem to result from lines of minute fluid cavities. Lastly a few large dark-brown crystals occur mixed with or superimposed upon the amazon-stone crystals. They are somewhat muddy, and not well formed.

Specular iron in small quantity and in minute scaly crystals coats the free faces of the quartz.

There were found, on the sides of some of the cavities which occurred in the centre of the vein, three spherical masses of a cream colour. They had a radiated crystalline structure, from the surface of which free crystals protruded; but these were without lustre, and were too ill-defined for determination of their form. The centre of the spheres had a tremulous lustre, and was of a pale brownish-white colour.

Two of these spheres were of the size of tennis-balls; the third, which was used for analysis, was small.

They were disposed upon the surface of quartz and amazon-stone crystals, the free summit of the crystals projecting into the cavity, which contained a little water. Minute crystals of specular iron sometimes lay transversely to their fibres, and also did the green mineral next to be described.

The analysis of the sphere yielded—

Strontia	58·846	
Lime	8·529	
Carbonic Acid	32·305	
	99·68	(H.)

There was also a loss of ·099 per cent. in the water bath.

This is, therefore, a calcareous *strontianite.*

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Dr. Thomson has given an analysis of brown strontianite from Strontian, which agrees very closely with this in the quantity of lime; but that analysis has lately (? on account of the lime) been dropped out of books of reference.

The specific gravity of this strontianite is 3·447.

The last substance which has been formed in the regular separatory sequence which has occurred in the formation of this exfiltrative vein, proved to be new; and I have attached to it the name of *Bhreckite*, from the hill upon which this most extraordinary mass of rock lay.

It occurred in such very small quantity, that nearly the whole had to be employed for the analysis.

This substance was deposited upon the surface of the crystals of brown quartz; and its immediate associates were the *specular iron* and the calcareous *strontianite*.

In appearance it resembles a very fine-grained dense *aphrosiderite;* but its colour, being a bright apple-green, was nearer to that of *celadonite*.

It was minutely granular or scaly; it was soft and friable.

The portion analysed was spread out under the microscope, when even with a high power it was to all appearance uniform and pure. It occurred in very minute lustrous scales.

The analysis, executed on ·484 grammes, yielded—

Silica	34·917
Alumina	7·158
Ferric Oxide	12·718
Ferrous Oxide	2·105
Manganous Oxide	·414
Lime	16·082
Magnesia	8·264
Water	17·768
	99·655 (H.)

Of the above water 1·033 was lost at 212°.

There were traces of alkalies, but there was not enough material to determine them upon; separate quantities having, of course, to be used for the determination of the ferrous oxide, and of the water.

The mineral was freely soluble in chlorhydric acid.

By this feature it may be distinguished from all the so-called "chlorites," with the exception of *glauconite*; it likewise serves to distinguish it from *celadonite*, which of all minerals this most resembles.

From *Delessite* and the scaly varieties of *saponite* (which *are* soluble in

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chlorhydric acid), it differs in virtue of its large amount of lime; a feature of its constitution which also serves to distinguish it from *glauconite*, and from the chlorites likewise.

The calculation of its atomic constitution is as follows:—

		Atoms.			
Silica	34·92	1·164		8	36·28
Alumina	7·16	·14	·3	2	7·78
Ferric Oxide	12·71	·16			12·1
Lime	16·08	·574	1·04	7	17·69
Magnesia...	8·26	·413			8·46
Water	17·77	1·974		13	17·69

Atoms.

$$\dot{R}7,\ \ddot{\dot{R}}_2 2,\ \ddot{S}i\,8,\ \dot{H}_2 13,$$

which gives the percentages of the last column.

This is the only chlorite-like mineral which contains lime in quantity; if established by occurrence elsewhere, it will stand next to *chonicrite*, and in composition it is not far removed from the *metaxoite* of Arppe.

The boulder which yielded this extraordinary association of minerals, was broken up by dynamite. It was found to be perfectly fresh and unaltered by aqueous percolation, or accession of air. At a distance of about a couple of feet from the vein there occurred small cavities, the sides of which were drusy with minute crystals of felspar and hornblende.

A pale yellow almost white incoherent powder, which was moist, and somewhat soapy to the touch, filled these cavities.

When freed as far as possible from grains of the matrix, it yielded upon solution in weak acid—

Insoluble and Silica	2·615
Strontia	54·222
Lime...	8·201
Magnesia	·846
Potash	·485
Soda	·261
Alumina	·879
Ferric Oxide	1·428
Manganous Oxide	·692
Carbonic Acid	29·948 to 30·728
	99·643

The analysis was made on two different portions, and can only be approximate.

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This is a most singular result, as it shows strontianite to occur in a granular form.*

The Syenite of Lairg.

Murchison, in his "Generalised Sections," depicts the syenite of Ben Loyal as tilting up the contact rocks to east and west; and though he does not state that he actually saw such tilting at the spot, he throughout writes as if there was no question as to the syenites being eruptive.

I failed to find any spot near Ben Loyal where the contact was seen. Near Lairg, however, the circumstances for such examination are altogether favourable, as an actual contact can be seen in a small quarry half a mile from the village; and the railway-cutting, a mile or so to the south, also affords more than one point whence instruction may be gleaned.

The writer, however, had his attention more immediately directed to the question as regards the rocks *in the vicinity* of the syenite, through Dr. Joass having again guided him to a mineral locality situated among such rocks. Dr. Joass had procured some new Sutherland minerals from a pensioner; he sent them to the writer; and as the locality was one which in a former year had appeared to Mr. Dudgeon and the writer as one of marked interest, it was lately examined; and on the first occasion of such examination the writer had the advantage of Mr. Hudleston's experiences.

The district in question is that which impinges upon the great mass of syenite, upon its west margin. It showed rocks so altered and granitic in their nature that Mr. Dudgeon and I agreed to carry the line of the syenite, nearly two miles to the west of the junction as laid down by Cunninghame, by Nicol, and by Geikie. Further examination, however, satisfied me that though highly metamorphosed and syenitic in parts, it was gneissic as a

* Amazonstone was first stated to have been found in breaking up a boulder at Ribigill at the foot of the great north precipice of Ben Loyal. This was thought to be an error, but in the year 1882 I was presented by Mr. Wisdom with a portion of a crystal of amazonstone, which he broke out of a wall about 60 yards from Ribigill; and he stated that he thought he could see a vein running up the face of the cliff. Dr. Joass, in a letter of date March 20th, 1883, writes:—"The other day a good specimen of amazonstone, containing part of a large crystal of tourmaline, was brought to me as found in the burn running out of Lochan Hacon, where the rolled specimen was got which contained small flakes of talc, and which you thought curious. If is of interest to know that the vein with the amazonstone comes to the surface somewhere on the Ben Loyal side of the Tongue strath, either in this burn or on some of the slopes overhanging it." This crystal of *tourmaline* is the first found in Sutherland. The absence of that mineral from the red granite and other veins of the Hebridian rock is a fact worthy of note.

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whole,—had no connection either geognostically or in constituents with the syenite of Lairg,—and, indeed, that there was a distinct belt of less highly metamorphosed gneiss interposed between the altered districts and the true syenite. In my map, therefore, the boundary line of the syenite was again carried back to its old position.

The district is termed the Gruids; it stretches two or three miles west of Lairg, and is somewhat less in extent in a north and south direction.

The rocks here fairly well exhibit transitions from gneiss into a granitic rock; but the transition is incomplete, as there is no mass of perfectly transmuted rock. This change takes place through an increasing dominance of bands of metamorphic segregation.

The general appearances associated with this change, I have described in my papers in the Transactions of the Royal Society of Edinburgh,* so that I now only glance at the local features.†

At the west end of the district towards Rhian and Druim Baltifiar, the country has been much scoured by ice, and numberless false boulders strew the surface. Observation shows that these have been only pushed about, and not transported any distance. They consist merely of portions of rock torn off the protruding, because less disintegrated, bands of the rock. Closer observation also shows that such bands had been less disintegrated, in virtue of their having been the more highly altered,—the more perfectly metamorphosed.

Here the most singular variety is one which presents itself at first sight as a dull green felspar, with imbedded semi-fibrous hornblende, and some *Biotite*. Inspection with the microscrope shows that if this variety contains hornblende at all, it is in a form difficult to recognise as such, as it polarises with a uniform structure and an oily roundness of the edges.

Passing to the Ord Hill, the appearances which are common to veins of dominant change are well seen; the abruptness of flexure, and the suddenness with which they thicken, thin, or disappear, is most marked. These bands are of a beautiful and characteristic syenite, of which the felspar is to a great extent of a lively brick-red. It is in well-pro-

* Vol. xxix. p. 6.

† As the *modus operandi* of such changes can be most easily studied by aid of the microscope, I have adopted what I considered the simplest and most satisfactory method of wide-spread publication,—namely, placing sufficient masses of each rock in the hands of Messrs. Cole & Co, St. Domingo House, Oxford Gardens, London, W. All subscribers to the highly deserving and admirably conducted enterprise of this Company will receive slices.

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nounced crystals, and the foliaceous hornblende is also distinctly segregated apart.

No connection whatever can be discovered between the rock of this hill and the syenitic mass at Lairg. Indeed, as we approach the river Shin, we find much more massive veins,—less flexured, and consisting of white felspar and quartz in amorphous agglutinations.

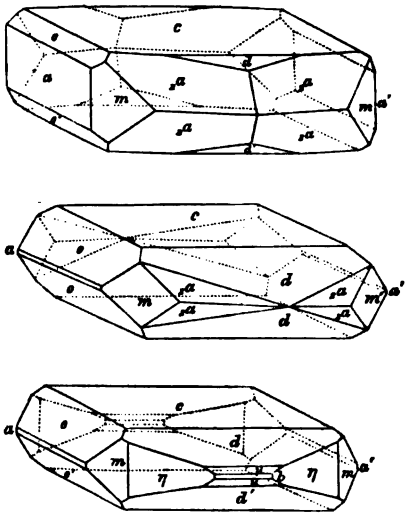
The district is one which should be studied, along with microscopic sections of its rocks, by all interested in metamorphism.

These rocks show little change, except in the syenitic belts, and they maintain unaltered the ENE dip which is normal to the district.

Minerals.

The minerals forwarded to me by Dr. Joass as from this district, consisted of blue *fluor* in granite; *specular iron*, of a blue-black colour and considerable thickness of crystal, adherent to syenite; crystallised *chalcopyrite*,—and finely crystallised *rock crystal*.*

On my first search with Mr. Hudleston I found only a specimen which carried rock crystal,—prismatic and doubly pyramidal, along with crystals of pinkish baryte, in the three interesting forms drawn. This was broken out of a loose block.



* There was also a small specimen of *cryolite* with crystalline *sederite*. This must have been "picked up" by the pensioner in some other way and place.

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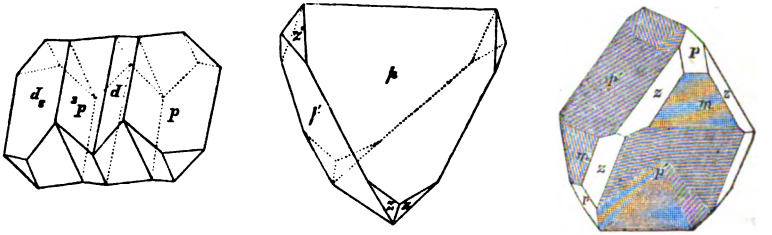
I afterwards obtained *in situ* specimens which carried *chalcopyrite* in the following four forms; one specimen also had a twin so complex and



so imbedded in the rock that I failed to make out its form. This specimen had also *rock crystal* in the form drawn; it was more pellucid, and in every way finer than I have seen elsewhere in Scotland. The rock crystal was imbedded in calcite.

A piece of chalcopyrite sent by Dr. Joass had the form of fig. 5.

I could find neither the *specular iron* nor *fluor*. The occurrence of the latter at this spot I doubt, as the matrix of the specimen is not here found.

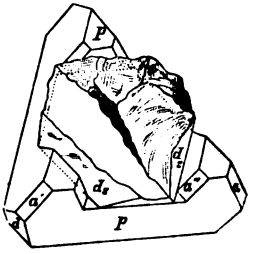


Fig. 5.

The question as to the igneous nature of the great mass of the syenite of Lairg is one which, from the excellence of the exposure in the little quarry to the east, can be entered upon by all.

A large sharp-angled fragment of the adjoining gneiss lies impacted in, and surrounded by the syenite; this had also overlapped it, but the cover is now removed. The syenite will also be seen to have insinuated itself into rents of the gneiss, which forms one side of the quarry. The

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material which fills these rents is much of the same size of crystal-grain as is the general mass of the syenite. The gneiss is nearly flat-bedded in the neighbourhood, and the impacted fragment lies also in a horizontal position in the paste. The actual junction of the two rocks seems to have been fortuitously struck. The rock of the fragment appears little if at all altered. Veins from the syenite enter its rents, and these have a crystalline structure, which is more minute than that of the main mass. This must be read as pointing to a more rapid cooling of the substance which filled the rents; in other words, to the intrusion of a molten mass into a cold mould. At one spot only does any crystalline structure seem to have been induced in the fragment, and there even it is obscure or doubtful. The fragment is in no sense *resolved*, even on its edges.

That the rock is igneous it would be difficult to disprove, but there is no disturbance, and no evident alteration. The only direct evidence, thus, in favour of such a view, seems to lie in the more minute structure of the smaller of the veins thrown out from it; – an argument not of much force, seeing that the larger rents are normal in size of grain.

The syenite itself forms the greater part of the higher ground between Strath Fleet and Strath Brora, extending eastward to about Morvich.

To the eye it has a darker shade than that of Ben Loyal. An examination with the lens shows it to contain much of a striated white felspar, some orthoclase also white, and little quartz. It has more hornblende, and especially more dark coloured mica, than is present in the northern mass. Here, indeed, the mica is in excess over the hornblende; and not unfrequently has segregated apart in flat masses the size of the hand. These show a laminated arrangement of the mica, the flakes of which curve round a common centre. This mica, and indeed all the dark mica of the district, is much more strongly dichroic than is the hornblende.

The rock also contains minute *sphenes*, generally with rounded angles. They are in simple forms, hair-brown, of high lustre, and translucent.

Cunninghame states that he saw well crystallised forms in the neighbourhood of Pittentrail.

Examination with the microscope shows the striated felspar to be almost invariably twinned, down the centre of each crystal. Its striation is minute, but ill-defined.

The orthoclase also is ill-defined, both as regards want of definite form, and absence of characteristic structure. Opaque and white portions occur,—sometimes diffused, sometimes in isolated patches. No speck of titaniferous iron is visible. The quartz has fluid cavities large and small; it

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also contains imbedded portions of curvilinear outline of a more hyaline quartz, which portions are devoid of cavities.

Colourless hexagons, which may be *apatite*, are abundantly present. The sphenes are invariably flawed, the fissures being curvilinear, and transverse to the longer axis of the crystal.

The most characteristic feature is the presence in both of the felspars of minute crystals of an apparently colourless mineral in forms similar to the fourth figure of orthoclase drawn in the present chapter. These endomorphs comparatively rarely occur in the striated felspar.

While the crystals of apatite occur embedded in all of the components of the rock except in the sphenes, and in all lie in every position, this is the exception with the colourless crystals which occur in the felspars. In the striated felspar they are arranged almost always with their longer axes accordant with the long axis of the felspar. They are thin, almost scaly, and the scales lie at right angles to the striation. Seen in the midst of the striation they present an appearance like a number of square-ended fishing punts floating down a stream.

It is, however, in the orthoclase that these endomorphs are most abundant and most regularly positioned. That position seems to bear out in its entirety the view I submitted as to the crystal fabric of the Tongue amazonstone.*

The portions of the orthoclase which contain these endomorphs, it has to be remarked, do not show either the "corded structure," or ordinary cross-hatching; it is only the position of the endomorphs themselves in relation *to the faces of the orthoclase* which is in such portions disclosed.

In ordinary light they are easily seen, in virtue of the sharpness of their edges, and of an increased transparency of the slice at the spots where they occur.

In polarised light they are seen to have a feebler depolarising effect than has the orthoclase in which they are imbedded. Not merely can their marginal edges be seen, but their transparency permits of the edges of their medical planes appearing. The most distinct show the figure of a plagioclastic felspar. Generally, indeed almost always, they lie in only one position; this is, they are bedded on the face *m* of a plagioclastic felspar, and their terminations all point the same way. In addition to *m*

* The examination of numerous sections supplied to me by Messrs. Cole with a view to the description of the rock in their "Studies in Microscopical Science" has enabled me considerably to extend my knowledge of this rock. Slices can be obtained from Messrs. Cole & Co.

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they show the faces *p t l* of albite; and that they are plagioclastic is shown by the face *p* of one summit always being seen *through* the crystal.

They polarise so feebly that a Leeson's goniometer does not suffice for measuring any of their angles, but with Ross's I got about 114°55, as the angle which the edge between *t* and *l*, and *p* and *m*, form with each other.

From the step-like, or in-and-out nature of the composition face of the twin, and from the fact of the imbedded crystals being in an inverted position on the two sides of the line of composition, I conclude that the orthoclase is present in Carlsbad twins, and that the endomorphs rest with their faces *m* parallel to the face *a* of the twin.

The chief interest connected with these minute crystals lies in their relationship to the comb-like or cross-hatched structure. It has been remarked above that the slices which show the crystals lying on their faces *m* show no cross-hatching. Again, it is found that the rock, when sliced in the direction which shows cross-hatching, presents no appearance whatever of any of these crystals *in a recognisable form;* yet, from their abundance, they must be present in the slice. In describing the amazonstone, I showed that the comb-like or cross-hatched structure (taking them as one) is seen only in slices parallel to *c* of orthoclase; and that the wedge-shaped crystals which form the comb-like structure lie parallel to *b*, and "are transversely barred or broken up, as if themselves built up of myriad crystals."

We see, both in the amazonstone of Tongue, and in the cross-hatching here, that the *bars* have a feebler depolarising effect than any other part of the structure; and we know that minute flat crystals disposed parallel to *a* would be at right angles to *c*; and hence, would cross-cut flat or wedge-shaped crystals which lie parallel to *b*. Hence, we may conclude that these endomorphs form part of the structure in cross-hatching, and that the special part is that arm of the cross which lies parallel to *a*.

So considerable a proportion do these minute crystals bear to that of both of the white felspars, that no very definite information as to their nature would be furnished by analysis; and it is, indeed, from analyses of the constituents of exfiltration veins which occur in the rock, that the striated felspar has been referred to oligoclase. Such veins occur near the summit of Cnoc Dubh, and one such (now entirely quarried away) furnished, from this quarry itself, the material analysed by me.

We are fortunate, in many ways, when such veins occur. That they have resulted from the rock throwing out, from its own mass, the material of its own substance in a state of solution, (under pressure), to fill rents which have traversed it, there can be no reasonable doubt.

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While it may be maintained that such veins cannot supply us with the whole of the materials of the general mass of a rock, as the more insoluble cannot be swept from their original position, in virtue of their insolubility,—it has to be replied, that such veins *do* contain substances usually quoted as types of insolubility. Such are *baryte*, *ilmenite*, *magnetite*, *sphene*, and *quartz* itself.

More than this,—on account of such veins presenting us very generally with giant crystallisations of the several constituents of the rock, they exhibit these unmistakeably, even when no trace can be seen elsewhere in the rock.

These plugs of exosmotic transference have the following features, which speak to their mode of formation :—

Their structure is similar on their opposite sides; they show more or less perfectly a series of bands of successive growth; the size of the crystals which they contain increases towards the centre of the vein, even as regards undue increase in the volume of that extremity of an individual crystal which points to the centre; any vacuous spaces which may occur lie in the centre of the veins, and into these the free summits of the crystal growths protrude.

A section of such a vein thus forms a marked contrast to that uniformity of size of crystal-grain which gave its name to *granite*.

In the latter, the crystallising force latent in each constituent, seems to have been asserting itself in independence, during the time that the rock, apparently as a whole, was rapidly solidifying; and so each substance was interfering with those which touched it all round its periphery. No perfect crystals could so be formed; and a structure crystalline, but not crystallised, resulted.

In the vein, there was no such rush to solidity. There was still self-assertion,—as selective cohesion called the molecules of the several individual substances, each to consort with its fellows. There was mutual interference through *lateral* contact, but free forward extension into not a vacuous space, but into space filled with a readily displaceable fluid. So there resulted the drawn-out crystallisations,—the graphic lettering, and the capping of crystals, which are typical of such veins; the individual segregation into large and pure crystals, more or less in parallel arrangement, as if under the guidance of a common polarity,—in contradistinction to a confused congeries, in which each crystal seemed to be a law to itself alone. There ensued the large crystallisations so generally obtained from *solution*,—as distinguished from the minuter individuals got by the chilling of masses which had been liquefied or rendered plastic *by heat*.

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But the crystallisations which such veins supply are exceptional, not merely as regards their size, and occasionally their regularity of form, they are very much more exceptional as regards the uniformity of their structure,—in other words, their physical and chemical purity. Therefore, in such may we much more rationally hope to descry optical properties special to each mineral, than in the contaminated individuals occurring in the *mélange* of a rock mass. During the slower process of their formation from watery solution, not only has each molecule ample time to find its way to its appointed place in the crystal fabric, but it has also time to evade, instead of sweeping before it to incorporation, any alien substance which may lie in its path.

Endomorphs, microliths, and their congeners are hence very much less frequent in the giant crystals of veins, than in those of a rock mass.

As it has in the past been the custom of the chemical mineralogist to glean from this pure source, so should it be the practice of the petrologist to learn therefrom the optical properties of the mineral constituents of rocks also. It would also be well that he should commence his investigation of rock structure upon slices cut from its veins. Above all would it be well with him if, as the preliminary of all, he called in the chemist's aid, authoritatively to tell him what it was that he was looking at. Not till he does so, is he a worker in *a fixed science*,—not till then are his steps sure. As exfiltration veins are the hope of the crystallographer and of the chemist, so should they be the sheet-anchor of the lithologist.

We have already seen the wonderful productions of one such vein in the syenite of Ben Loyal; those in the syenite of Lairg cannot compare therewith; still from these veins alone could I here get material pure enough for analysis.

The vein in the little quarry was about two feet in width; *orthoclase* and *oligoclase* formed its mass, occurring in nearly equal quantity. The crystals of each were about two inches in length and breadth.

Among these there were imbedded crystals of *Haughtonite*, of *Allanite*, of *sphene*. In cracks there also lay a minute quantity of a substance of a purple colour. This much resembled *yttrocerite*, but probably was *fluorite*: it did not, however, lose its colour when heated.

The orthoclase was of a pale pinkish tint: its cleavage angle was 89° 59′, its specific gravity 2·555.

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It yielded—

Silica...	62·616
Alumina	19·634
Ferric Oxide	·064
Magnesia	·636
Lime	·604
Potash	13·72
Soda	2·92
Water	·18
	100·324 (H.)

The oligoclase is frequently imbedded in, or sheathed by, what little quartz there is in the vein. It occurs in somewhat more regularly defined crystals than the orthoclase, and, being occasionally imbedded in the latter, probably solidified somewhat anteriorly to it; still the crystals of both have so interfered with each other that no definite forms were observed.

The oligoclase crystals are of a yellowish cream colour to white; opaque and dull, not visibly striated, but cleave so readily at the twin face as to appear somewhat foliated.

In breaking up a large crystal a portion was obtained from its centre which was colourless, translucent, and distinctly striated. As this seemed to indicate that incipient weathering had obliterated the reflection which discloses striation, both the opaque and the transparent portions were examined.

The specific gravity of the transparent variety was 2·618, its cleavage angle 86° 15′. The opaque variety had a cleavage angle of 86° 10′.

Respectively they yielded—

	Cream Coloured.	Colourless.
Silica	62·052	62·818
Alumina	22·444	22·919
Ferric Oxide	·352	·156
Magnesia	·14	·08
Lime	4·2	4·25
Potash	·86	·84
Soda	9·22	8·53
Water	·36	·29
	99·628	99·878 (H.)

Chemistry has not solved the riddle here. In the first place the structure is not absent from the portions which were in contact with the

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orthoclase *on account of any contamination with it*,—for these portions have in every respect a more oligoclastic composition than has the centre. Again, it cannot be said that there has been afforded any proof of the incipient decomposition which presented itself to the eye;—because the alkalies are, in the opaque portion, in excess of their quantity in the apparently fresher parts; and the alkalies should, in virtue of the decomposition which results from surface exposure, have been abstracted *first*.

The ready cleavage along the faces of the planes of composition, shows that the compound structure remains in those parts where it cannot now be discerned. It would be merely giving the difficulty the "go-by" to say that there must be some change in molecular structure resulting from exposure to light.

The *Haughtonite* which occurs here has, in those crystals which lay on the surface of the rock, suffered some small amount of change; for they have that dark green colour which I have found to take the place of the original dark brown of the unaltered mineral. The crystals which occur in the centre have this latter colour in marked freshness.

Here the crystals have assumed a habit which is frequent,—characteristic indeed of the mineral,—namely, running out in a single direction. They are about half an inch in width by two to three in length, and have sometimes a tortuous course. Where brown, they have a brilliant vitreous lustre; where green it is more or less greasy.

No plate large enough to determine the specific gravity, or transparent enough for determining the optical properties, could be found. The mineral yielded—

Silica...	35·555
Alumina	16·694
Ferric Oxide	1·883
Ferrous Oxide	18·037
Manganous Oxide	·694
Lime...	2·722
Magnesia	8·472
Potash	9·896
Soda	·105
Water	5·714
	99·722 (H.)

The crystals of *Allanite* occurring here show no forms; they are larger in size than any I have seen in Scotland, with scarce an exception. They are here, as elsewhere, surrounded by a brown stain, when imbedded in one or other of the felspars.

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The *sphenes* also are large, but ill-defined; they were quite different in appearance from those in the syenite, being dull brown and opaque.

One crystal, which differed from the others in having much resemblance to *Keilhauite*, but which also had somewhat of a decomposed appearance, was analysed. It was in the form of the arrowhead twin, only one half of which was present, but this was about three-fourths of an inch in length by one-fourth in thickness. It was dull yellow, much flawed, softer than sphene, and slightly earthy.

It was only partially decomposed by fusion with potassium sulphate, and was consequently again fused therewith. Finally, to make certain of the purity of the silica, the latter was again fused with Fresenius flux, and treated for titanic acid; but it yielded not a trace thereof.

There was got—

Silica	44·300
Alumina	·585
Ferric Oxide	7·165
Manganous Oxide	·700
Lime	1·400
Magnesia	45·910
Water	·131
	100·191 (H.)

It therefore would appear to be a pseudomorph; and the replacing substance is chemically much of the nature of *olivine!*

Granite of the Ord.

In this coarse-grained, apparently igneous granite, Dr. Joass has found *fluor* extending through a considerable stretch of the rock; but chiefly in the neighbourhood of Culgower and Loth. It occurs in thin reticulated veins, of a purple colour, with only traces of crystallisation. In some parts it seems to act as a cement to the crystalline components of the granite.

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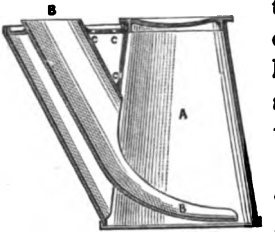
A Portable Blowpipe Lamp.

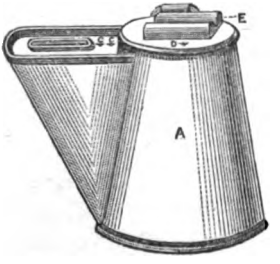
By J. Stuart Thompson.

[Read October 24th, 1882.]

WHILE making some experiments with a form of miner's lamp, which has recently been introduced for the purpose of burning soft paraffin wax in place of tallow, it occurred to me that this wax, which melts at about 38°C., would be a very suitable fuel for a portable blowpipe lamp, being both cheap and cleanly. Having thus got a suitable fuel, the next step was to devise a lamp to burn it, and after one or two trials the form shown in the annexed sketches was adopted. From these it will be seen that in shape it somewhat resembles an ordinary miner's lamp; the exterior form, however, may be altered to suit special requirements, without interfering with the working of the lamp; thus it may be made square or oblong for packing into a cabinet.

The following is a description of the lamp:—the body A is made of thin tin plate or sheet brass; the wick tube or holder B is formed of sheet copper, and is carried down into the interior of the lamp, as is shown in the sectional sketch; the object of this is to conduct a portion of the heat to the paraffin, and so liquify it. The small holes CC in the saucer surrounding B, in the body of the lamp, are for the purpose of allowing any overflow of wax from B to escape back into A. The lid or cover of the lamp is perforated at D in order to admit air to the body of the lamp, so preventing any alteration of pressure taking place there, which might interfere with the rise of the melted wax in the wick. The channel E (shown only in the perspective elevation) serves as a support for the nozzle of the blowpipe. The wick should be a soft cotton one, as loosely woven as can be procured, and care should be taken that it fits the wick tube as tightly as possible.





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In order to start the lamp, it is advisable to fill it at first with *melted* paraffin ; this is done in order that the wick may become saturated with the wax ; but thereafter the paraffin may be added in small pieces, the heat of the lamp being sufficient to liquify it. In place of having the rest E on the lid of the lamp, a very convenient and portable arrangement is to solder on in its place a small piece of brass tube, in which slides a blowpipe nozzle, to which, by means of a piece of india-rubber tubing about 18 inches long, a mouthpiece is attached This arrangement has the advantage that both hands of the operator are thereby left free to manipulate the substance under examination.

Lamps of the above pattern and soft paraffin wax can be procured from Wm. Hume, 1 Lothian Street, Edinburgh.

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On the production of Coke suitable for metallurgical purposes from refuse Small Coal of Collieries.

By G. M. Ward, M.S.E. (Abstract.)

[Read October 24th, 1882.]

THE author in this paper points out the desirability that coke for smelting purposes should not only be capable of producing high pyrometric effects, and of sufficient strength to bear the immense burden of the column of material in the modern high furnaces, but should be especially free from sulphur. The separation in the first instance of the solid impurities is effected by washing the small coal, prior to its being coked, in a coal washing machine, by the agitation of the coal in water, whereby the various substances arrange themselves in layers according to their specific gravities; the coal, which is the lightest substance, forming the uppermost layer, and the heavier substances, viz. the slate, pyrites, and other solid impurities, forming the lower layers, the slack being deposited on a grid through which the agitation is given; and the machine is so constructed that the agitation shall not only divide the substances into layers, but gradually separate and remove the pure coal. The ovens are constructed so that the remaining volatile matter is perfectly and economically expelled. The pyrites being largely separated from the slack during the washing process, the sulphur is further reduced to a minimum by watering the coke at its highest temperature immediately after the coking process is completed, and it is desirable to continue the watering after the heat has ceased to be sufficient to convert the water into steam, as there remains in the coke sulphur in a state capable of being washed out. The author tells us that coke which has been condemned as too sulphurous to be used for smelting purposes has, after exposure to the weather for several years, been used with satisfactory results. Next to its purity, density and hardness are the tests of coke which has to be subjected to the blast and bear the burden in a furnace; density being obtained by reducing the coal to small and equal particles, and hardness by coking at high and uniform temperature.

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Nickel Ore from Piney Mountain, Douglas Co., Oregon.

(By J. W. Hood, M.D. *San Francisco Bulletin, June 20th*, 1882.)

[Read October 24th, 1882. Abstract.]

THE Oregon Nickel is found in two varieties, which analysed prove to be almost identical with the ores from New Caledonia—Garnierite and Noumeite—and occur under precisely the same geological conditions.

Comparative analyses of Oregon and New Caledonian Nickel Ores :—

	Oregon ore. A.	Oregon ore. B.	Garnierite.	Noumeite.
Silica	48·21	40·35	47·23	47·90
Alumina and Iron Oxides	1·38	1·33	1·66	3·00
Nickel Oxide ...	23·88	29·66	24·01	24·00
Magnesia ...	19·90	21·70	21·66	12·51
Water...	6·63	7·00	5·26	12·73

Oregon Ore, A. Amorphous—Hardness, 2·5 ; S.G. 2·45 ; colour, pale apple green, becoming lighter by exposure. Adheres to tongue ; not unctuous. Does not fall to pieces when placed in water.

Oregon Ore, B. Amorphous—H=2—2·5 ; S.G. 2·20 ; colour, dark apple green, becoming lighter by exposure. Adheres to tongue ; unctuous. Falls to pieces in water.

Garnierite. Amorphous—H=2—2·5 ; S.G. 2·27 ; colour, apple green. Adheres to the tongue ; not unctuous. Falls to pieces in water.

Noumeite. Amorphous—H=2·5 ; S.G. 2·58 ; colour, dark apple green. Does not adhere to tongue ; unctuous. Does not fall to pieces in water.

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On some Rocks from the Saas-Grat, compared with Erratic Blocks from the neighbourhood of Lake Leman.

By Captain Marshall-Hall, J.P., F.G.S., &c.

[Read December 12th, 1882.]

The following are chiefly notes of a longer paper read April 5th, 1882, before the Société Vaudoise des Sciences Naturelles.

For some years familiar with the valleys of Anniviers, St. Nicklaus, Zermatt and Saas, the author has made a study of comparison between the above rocks *in situ* and erratic specimens of the same nature. The want of a laboratory and of more than a travelling microscope with polarising apparatus render his researches so imperfect that a more complete report upon these rocks must be deferred.

In the neighbourhood of Geneva, amongst other glacially transported rocks, are specimens of Euphotides, Serpentines, Eklogites, &c. found *in situ* in but few localities in Switzerland: the Euphotides especially from the mountains above the valleys of Erin and Saas; the Serpentines, on the other hand, from several other valleys on the same (the south) side of the Rhone.

Also, on the shores of Lake Leman, up to an altitude of not *less* than 2,500 feet above the sea, or 1,300 feet above the lake, the author has found numerous specimens of the rocks in question left by retreat of the great glaciers.

About Montreux and the lateral valleys, for instance, Serpentines and Euphotides are common, as also in the neighbourhood of Evian on the French side. After careful examination and comparison, the author is confirmed in the opinion generally held, that the origin of the Euphotides near Montreux is the Saas-thal; while those about Evian are from the Val d'Erin. Euphotides and some Serpentines are also found near Geneva; a fertile field is the corner of land at the junction of the rivers Arve and Rhone, a mile below the town.

Professor Alphonse Favre has given a description of these erratics in his geology of the canton of Geneva. On the other hand, Professor Bonney has described the microscopical appearance of some "gabbro" from the Evvolena district (Val d'Erin). The author has made sundry

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analyses of rocks from the Saas, the Anniviers and the Gremenz localities, as also from the erratic rocks about Montreux, Evian and Geneva; all these he has likewise examined under the microscope, together with many others. He owes to the kindness of Professor Bonney the notes of that gentleman's microscopical examination of rocks sent him by the author, giving results more complete than were possible with the author's limited appliances.

Before entering upon the description of these rocks, the author relates how he traced the Euphotides and Serpentines up the valley of Saas to a point marked 8150 *m* (= 10,890 feet approximately) in the excellent map of the Swiss Alpine Club. Monsieur Alphonse Favre had very kindly given him directions, results of his experience on a visit some years since, which enabled him to find his way direct to its foot, forming the last eminence of an *arête* descending from the Allalinhorn, and dividing the vast glaciers of Hochlaub and Allalin, the latter of which must be crossed in order to reach the base of the rocks, which took some three-quarters of an hour of slow and careful climbing to ascend. From this point, so far as had been ascertained, come the whole of the Euphotides found in connection with the Saas district. The steep sides are covered with characteristically angular blocks of nearly anhydrous rocks, passing in some places into altered hydrous and serpentinous masses. So far as could be ascertained in the time available without risk of being benighted, the mass is rightly supposed by Mons. A. Favre to be Euphotide. The next neighbouring rock masses were serpentinous. The whole ridge requires a clear day of exploration, which would involve the necessity of camping out an elevation of not far from 10,000 feet the previous night.

Amongst the specimens obtained from the solid rock, the following, selected by the author, possess interest, as bearing upon the degree of the metamorphism:—

1. Shows some schistosity. 2. More schistosity. 3. No schistosity, but evidence of metamorphism, in the opinion of Professor Bonney, in which the author joins, who observes that there are but few cases in which the beginning of alteration is not visible under the microscope. He attempted the approximate estimation of amount of change in various specimens, and there appeared to be a distinct relation between what could be detected by eye or with the microscope, and the amount of water expellable by ignition and *weighed* (as water) after previous long continued desication at ordinary temperatures, and finally at 100° C. Even the most characteristic Euphotides gave a small per centage of H_2O.

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He compares these rocks, taken *in situ*, with other erratic specimens. The following are instances, the letter B indicating the opinion of Professor Bonney.

A slice from a gully of the point itself, distinctly schistose, showing under the microscope grains surrounded by metamorphism and microliths of hornblende and perhaps mica. Some earthy matter (B) which may be a product of the decomposition of a felspar. Fragments of smaragdite here and there olivine, evidently in course of alteration. Here and there a passage from Euphotide towards a hydrous rock.

Compared with two slices from Veytaux and from Geneva (junction of Arve and Rhone), the unassisted eye would almost say they were detached from the same specimen as the last. Under the microscope we see the same constituent minerals similarly grouped as in the Veytaux slice, and after the same manner in the Geneva case the iron appears more oxidised. Think of the history of these stones—one detached from its native rock, the others transported so many miles, and exposed to atmospheric and aqueous action during so long a voyage and subsequently.

Another specimen—also from a gully—evidently secondary, under the microscope showing badly defined crystals of dichroic hornblende (B) with distinct cleavage. Grains of epidote (B also) and a felted mass without colour, resembling mica, but of two kinds, both orthorhombic; one, more fibrous, mica? (B), the other, less cleavable, more homogeneous and translucent, probably talc; actinolite present and (B) uralite and possibly zircon.

Another, midway up the point, consists principally of talc, hornblende, and actinolite. Schistose, and much altered.

A specimen from the incipient moraine at the base of the rock is Saussurite, with portions of smaragdite and small crystals of a hornblende, of garnets and, I think (also B), of mica. Saussurite seems more a rock than a mineral, in strict sense. At all events the author has never met with a homogeneous specimen. The same is the case with smaragdite, which contains diallage and some other mineral, according to Haidinger, pyroxene, and amphibole.

Another slice from near the base of the point resembles the last, with less talc and more hornblende, in small prisms. This is surprisingly altered, chipped off such a rock mass, still it contains but little hydrous mineral.

Mons. Henri de Saussure sent the author a specimen from Geneva, consisting of Saussurite which contained some felspar near labradorite (B and author), but not so brilliant as usual.

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Two other specimens, one from (M. H. de Saussure) Geneva, the other from (Mr. Collins) Cornwall, resemble each other so remarkably without the assistance of the microscope, that the author mentions them as an example of the imperative necessity of microscopic analysis. Under a moderate power, however, they appear quite different. The Cornish specimen consists, according to Mr. Collins, of bronzite, enstatite, and a plagioclastic felspar. The Genevese specimen is, subject to further examination, Saussurite and a hornblende, accompanied, as it seemed to the author, by diallage or some pyroxenic mineral. Both show alteration and hydration.

To pass over some descriptions, we quote the author's observations on some serpentinous rocks, not from the point of which so much has been said, and not needful to abstract here.

A Serpentinous rock from the glacier of Allalin, close under the precipices of the Inner Thurm (on its South border), compared with a specimen from Geneva (confluence of Arve and Rhone), presented both to the unassisted eye and under the microscope a most striking resemblance. The same with a specimen from the rock *in situ*, at present in England, and one from Geneva, due to the kindness of Mons. H. de Saussure.

The author, whose Paper was illustrated by the rock specimens quoted, and by slides under microscopes, as also by many other specimens, regretted that he should only be able to give so incomplete a description, and expressed a hope that on another occasion he should be able to enter upon minutiæ of the rocks described, and to discuss those from the Val d'Erin and Evian. He drew attention to the great difficulty of meeting with a quite unaltered rock, to the incipient hydration of every rock under their notice, to the difference, in some cases inappreciable even under the microscope, between rocks broken from the parent mass and stones found at so great a distance as Geneva, after so immense a lapse of time as must have passed since they were left exposed to weather by the retreating glaciers; and to the details of evidence of community of origin afforded by these beginnings of microscopical comparison between rocks from so widely separated localities as the Saas-Grat, Montreux, and Geneva.

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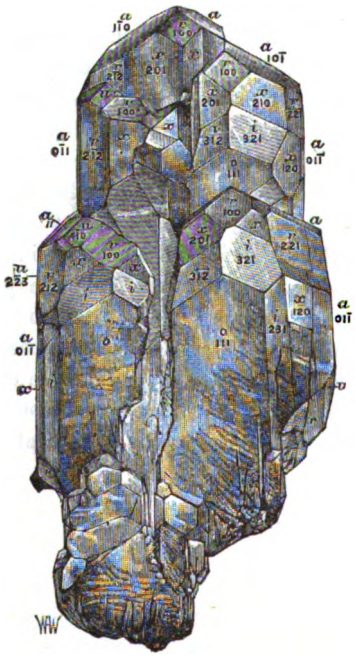
On a Crystal of Apatite.

By S. Henson.

[Read February 15, 1883.]

THE accompanying engraving represents an exceptionally fine group of crystals of apatite, found in the Untersulzbachthal in Salzburg. The dimensions are those of the original, its colour is white with a delicate tint of mauve. This group is the finest of three of the most magnificent specimens yet found at this or any other locality, the largest one having been deposited in the national collection of minerals at South Kensington, while the third was unfortunately broken.

The exceeding limpidity and brilliancy of lustre of all the specimens found at this locality, together with the numerous planes and their symmetrical development, render them of unusual interest: they are found in association with epidote, sphene, amianthus, and occasionally crystals of calcite, which are always of extraordinary beauty and purity. Epidote and amianthus are frequently found enclosed in the apatite, and, as is shown in the engraving, this particular specimen contains acicular crystals of epidote.



a0	90°	0′
i0	157	05
x0	139	47
xa	130	13
r0	124	20
aa′	120	0
ra	135	39
rr	131	14

Mr. S. Henson, of the Strand, through whose hands this specimen has passed, has caused a mould to be made and the accompanying plate to be engraved. The crystal planes have been marked, with his usual great kindness, by Professor W. J. Lewis, F.G.S., of Cambridge.

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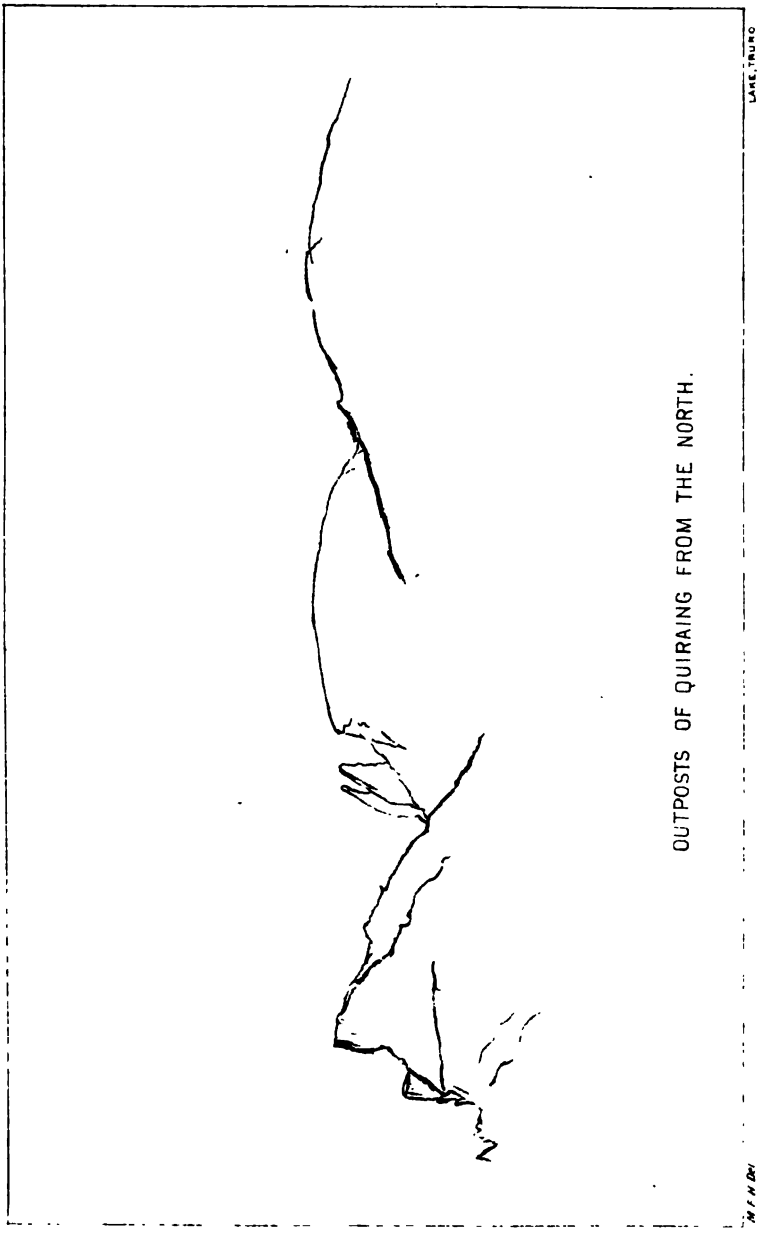

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SUTHERLAND AMAZON-STONES.

FIG. 1.

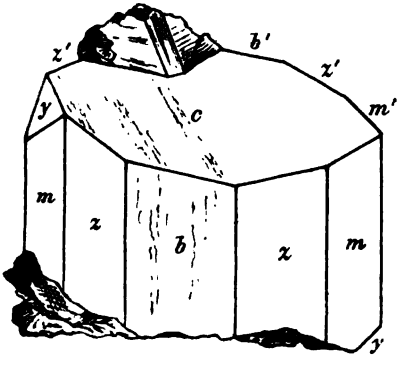


FIG. 6.

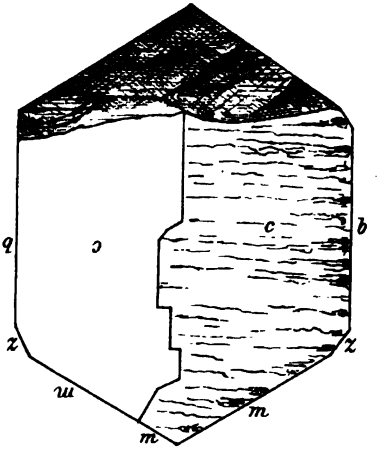


FIG. 2.

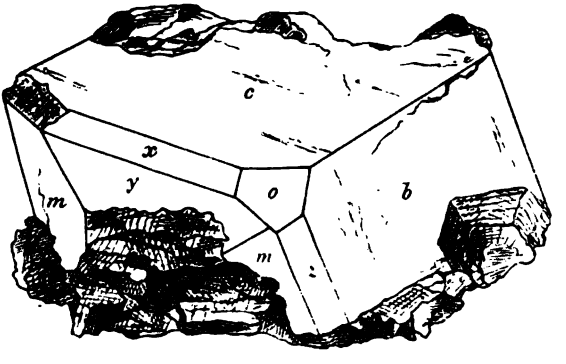


FIG. 3.

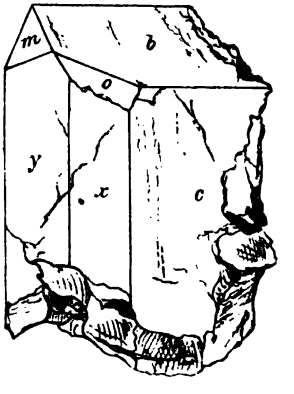


FIG. 4.

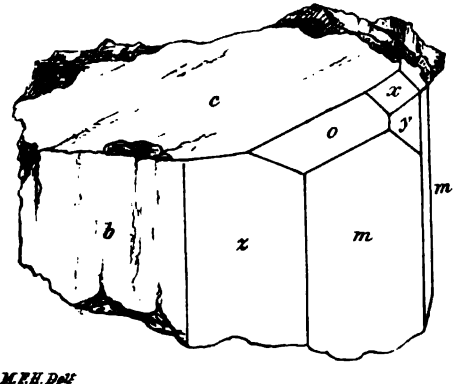
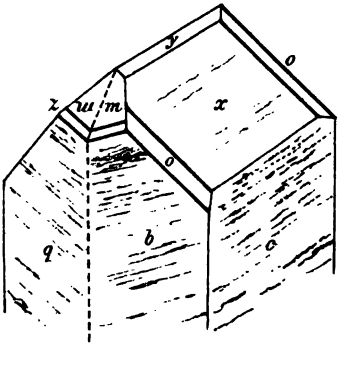


FIG. 5.



M.F.H. Delt

BRENDON & SON, LITH. PLYMOUTH.

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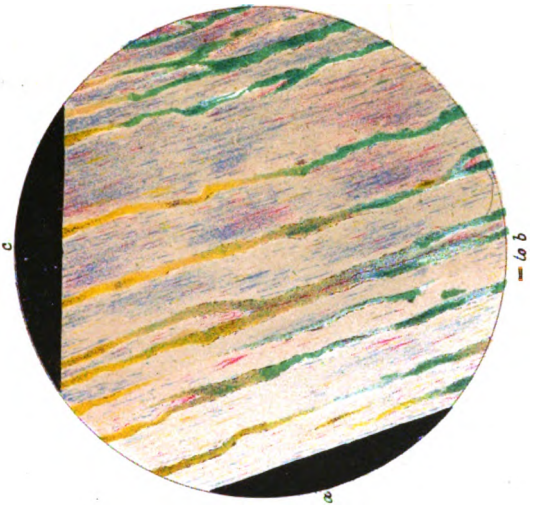

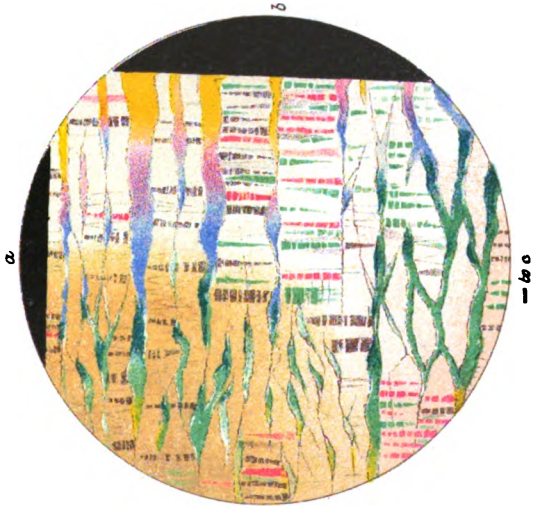

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

No. 25. AUGUST 1883. Vol. V.

On a recent Hypothesis with respect to the Diamond Rock of South Africa.

ERRATA TO No. 24.

Page ix., line 8, for "Thompson" *read* "Thomson."
Page 190, line 2, „ „ „ „
Page 191, *add* "The cuts are ½ full size."
Page 194, lines 9 and 11 from bottom, for "Euphotides" *read* "Gabbros."
Page 195, line 7 from top, after "appliances" *add* "whilst abroad."
Page 196, line 14 from top, after "manner" *add* ";"

in Shale	...	...	...	...	1 „
Black Shale	...	...	...	...	236 „
Total					275 ft.

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No. 25. AUGUST 1883. Vol. V.

On a recent Hypothesis with respect to the Diamond Rock of South Africa.

By W. H. Hudleston, M.A., F.G.S., President.

[Read February 15th, 1883.]

THIS paper forms part of a communication recently made to the Geologists' Association, with some additional matter relative to certain criticisms passed upon Mr. Dunn's hypothesis as to the origin of the diamonds.

It is taken for granted on this occasion that the leading geological facts are known, I will merely, therefore, draw attention to a generalised section of Kimberley Mine, where one side represents the wall or reef bounding the pipe itself, and is thus constituted:—

Red Sand	8 ft.
Concretionary Limestone	5 ,,
Yellowish Fissile Shale	20 ,,
Black Argillaceous Shale	10 ,,
Two thin bands of Black Dust in Shale	1 ,,
Black Shale	236 ,,
Total	275 ft.

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Then comes a band of andesitic dolerite, below which I at present possess no precise information.

The edges of these shales, as is well-known, are more or less turned up in contact with the material in the pipe, of which the following is a restored section—

Red Sand	8 ft.
Concretionary Limestone	15 ,,
"Yellow Stuff"...	80 ,,
Blue Stuff	282 ,,
Total	380 ft.

The excavations are no doubt deeper now, but I await further information on this point. It would seem that the concretionary or tufaceous limestone is three times as thick over the diamond rock as it is over the shales, from which we may infer that the diamond "marl," as it was once called, is richer in available lime than the more argillaceous shales.

The yellow stuff is merely a surface variety of the blue unaltered diamond rock, and it contains abundance of the larger pieces of shale and rounded rock fragments, such as are found in the friable matrix of this curious breccia.

The "blue stuff" is the genuine diamond rock, uninfluenced by superficial agencies, and if in any way altered, such alteration must be due to causes altogether unconnected with the surface; it is in fact a green earthy breccia containing fragments of shale, and various minerals of which the glistening plates of Vaalite are perhaps the most conspicuous. The minerals found in the diamond rock are so well known to most of us that I need not mention them here. Mr. Davies tells me that the bronzite grains which occur are in a condition much resembling those of meteorites.

Before proceeding any further to describe or theorise on the diamond rock, I ought to say a few words about the numerous doleritic rocks which pervade the shales or Karoo beds, both as dykes and sheets, and thus constitute an important geognostic feature which must be duly taken into account if we wish to understand the phenomena of the diamond rock itself. These doleritic rocks are probably for the most part known as basalts, and some of them help to form the walls of the other mines, to a greater extent than at Kimberley. All these rocks are described by MM. Fouqué and Lévy as having an ophitic structure; a term which puzzled and misled me for some time, until Mr. J. J. Harris Teall pointed out that those authors apply the term to a rock entirely composed of crystalline

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constituents in which the felspars are elongated in a certain direction, and in which the pyroxenic constituent has consolidated after the felspar.

I. The first group comprises the andesitic dolerites (or diabases ?). A sheet occurring in the shales on the north side of Kimberley is quoted with the following composition : magnetite rare, oligoclase, augite not plentiful ; chlorite and globular quartz as secondary products. Such a rock is probably what some people would call an augite-andesite, chiefly made up of oligoclase.

Other rocks of this class are quoted between Kimberley and the Vaal, differing from each other chiefly in the size of the crystals and in the secondary products, some of which are stated to be epidote, and even serpentinite.

II. The second group comprises the labradoric dolerites (or diabases), with which we may associate the anorthic dolerites.

1. A specimen of the reef at Old de Beers is described as a labradoric dolerite with peridote ; pretty much what we should call an olivine basalt, rather a common type of rock.

2. Next comes the labradoric dolerite with diallagic pyroxene, which we should probably call gabbro. Such a rock occurs on the Karoo plateau north-east of Beaufort West, consisting of diallagic pyroxene and large crystals of labradorite moulding the pyroxene, black mica in the pyroxene.

3. Lastly there occurs a class of rocks similar to the preceding, but containing olivine more or less intact, and various secondary products ; some of these are described as handsome types of peridotic rocks.

All these varieties of dolerite are found as "pebbles" in the diamond rock itself, to the consideration of which we must now return. I was inclined to think that we might regard the matrix or magma in which these various rocks and minerals are found as chiefly a mixture of talc and serpentinite, more or less adulterated with argillaceous dust and particles derived from the trituration of the shales, so that it would not be easy to obtain a pure substance for analysis. A specimen of the general mass, with the pieces of shale picked out as much as possible, was found to lose 6¾ per cent. in ignition. A small quantity of this loss may be set down to carbonic acid.

The softness of the rock suggests that talc enters largely as an ingredient. When Messrs. Maskelyne and Flight * examined specimens

* Q. J. G. S., Vol. xxx. (1874), pp. 406 *et seq.*

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of it, they came to the conclusion that the matrix consisted largely of an altered bronzite-like mineral which had the composition—

Silica	53·46
Alumina	·95
Ferrous Oxide	8·77
Magnesia	25·92
Lime	2·54
Water...	8·36
	100·00

But for the considerable amount of ferrous oxide this would nearly correspond to a mixture of talc and serpentinite. Call it what we choose, the matrix or magma is a hydrated ferro-magnesian silicate. The lime present may be in part derived from the shales, and partly from the doleritic rocks which furnish so many of the "pebbles" found throughout the mass. To these I must now direct attention.

"Pebbles."—Several specimens were shown to me some time ago by Mr. Davies of the British Museum. I shall mention only one—a hard yellow, speckled rock, consisting mainly of serpentinised enstatite and crystals of bronzite: it is from the yellow layer.

Mons. Chaper brought away with him lately a large collection of the rocks included in the diamond breccia: these were also reported on by MM. Fouqué and Lévy. Excluding the shales, the larger fragments belong to ophitic dolerites and rocks of the serpentine group, the smaller ones to felspathic and amphibolic rocks: it is rare to find clastic rocks other than the shales.

In the *serpentine* group we have—(1.) Rock consisting of serpentinite, with enstatite and olivine occurring as a "pebble" in the diamond breccia of Du Toits Pan.

(2.) Rock containing large crystals of olivine transformed into bastite and serpentinite occurring as a "pebble" in the diamond breccia of De Beers.

(3.) Rock consisting of serpentinite and talc, along with enstatite and magnetite occurring as a "pebble" in the diamond breccia of Bultfontein.

Next follows a large list of *doleritic* "pebbles" of various kinds, similar to the rocks already mentioned and partly described. These are the most numerous.

But we have not yet done with all the curiosities of the diamond rock. I say nothing about pieces of ostrich eggs and other things which have fallen, along with the sand drift, into cracks, as these are accidental.

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But pieces of coaly matter, and I believe compressed plant stems, derived in all probability from the Karoo beds, have been noticed in several cases. One of these coaly pieces is in the British Museum, and in the same place are to be seen some well-preserved fossil shells, which were exhibited by Mr. Davies before the Geologists' Association, and commented on by Mr. Etheridge. Like the other curiosities, they were most probably derived from the Karoo beds. People have at different times spoken of shells being found in the diamond stuff, but Mr. Davies has the credit, it seems to me, of having been the first to establish the fact beyond a doubt.

It is evident that some of the rocks contained in the breccia are fragments derived from the various *dolerites* already mentioned, most of which go by the name of basalt, whilst others are clearly gabbros. The more purely magnesian varieties of "pebbles" belonging to the *serpentine* group, of which I have just quoted several examples, must be derived from a rock whose original condition it is almost impossible to diagnose; the remarkable enstatite-bronzite rock originally described by Maskelyne belongs here.

The parent rock of this group may, in composition, somewhat resemble the stony meteorites, whilst in a hydrated form it has probably supplied the talcose* and serpentinous matter constituting the bulk of the matrix or magma of the diamond breccia itself. It is not a little singular that no rock belonging to the magnesian group is quoted in Fouqué and Lévy's table as occurring *in situ*, although there are plenty of all kinds of doleritic rocks with or without olivine. By the magnesian group I mean rocks mainly composed of ferro-magnesian unisilicates and bisilicates, such as enstatite, bronzite and olivine, with the equivalent hydrates, serpentinite, bastite, the altered bronzite, and perhaps talc.

That the whole of this matrix or magma once flowed is certain, and that it flowed upwards is equally clear from the turned-up ends of the "reef" in all the mines, whether that reef consists of shale or dolerite. It is also equally certain that the diamonds occur in this and *in no other rock*, the various basalts and gabbros being just as free from marketable diamonds as the shales themselves.

From what has been said, it is impossible to doubt the eruptive character of the diamond rock; though whether the singular breccia which now plugs the old duct at Kimberley was ever, in that portion of its course, in a state of igneous fluidity, as an ordinary lava-pipe

* Bronzite, according to Maskelyne and Flight

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might be, is by no means clear. Mons. Chaper believes that the course of several eruptions may be traced in the diamond rock of Kimberley, and that this fact is more obvious in the "yellow stuff" than in the "blue stuff." Whether such be the case or not, we must admit that the condition of the included fragments in the breccia, and especially of the shale, looks as though they had not been subjected to any intense heat, otherwise one would expect them to be fused at the edges, and more effectually incorporated in the general magma. And yet a most tremendously powerful expansive force must, during the period or periods of activity, have been perpetually urging the mixture upwards as the only direction in which it could find relief. I know of no force capable of doing this so likely as superheated steam. Indeed, there is no agency which seems to fulfil the conditions now exposed at the diamond mines, but water-gas at a moderate heat and under enormous pressure. How the action was originally set up, and whether it had any resemblance to that of mud volcanoes, it is not easy to say.

The very exceptional composition of the breccia, both of the matrix and the included fragments, may give us some inkling of the direction in which the problem will ultimately be solved. I have already stated that those samples of the matrix examined by myself consist mainly of a soft hydrous magnesian silicate. The alumina which it contains is probably —in part at least—the result of comminuted shale. The source of the lime, much of which now exists in the form of secondary products such as carbonates, is not quite so obvious. The shales themselves may contain a fair proportion of lime; and whatever they contain is sure to find its way into the diamond rock, which has invaded them in the manner we have seen. But there is another source from which the very considerable quantity of lime existing in the diamond rock may have been derived, viz. from the trituration and partial absorption of the numerous fragments of labrador dolerite, including, of course, the gabbros. These rocks, as we know, permeate the shales in all directions, and would yield, besides alumina, abundance of lime, much of which has speedily become carbonate. It is from this source that part of the lime in the tufaceous layer has been derived.

But after all the bulk of the matrix is made up of a hydrous magnesian silicate, the altered bronzite of Maskelyne. Here is the chief character in this motley piece, and what is its history? We seem to obtain a clue in the pseudo-pebbles of serpentinised olivine-enstatite rock to which I have already alluded. That some rock of this class supplied much of the

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material now constituting the matrix of the diamond breccia is more than probable.

But then comes the difficulty: we all know the intimate connection which exists between serpentinite and olivine, and how it is held by many that serpentine is largely derived from hydration of olivine rock; and with olivine we may associate the bisilicate, enstatite, which, like all magnesian silicates, seems unable to resist the attacks of water. That we can trace in the diamond rock of South Africa a very considerable element, representing generally what I may term an olivine-enstatite rock which has undergone alteration, is pretty certain: but the difficulty which presents itself to me is this, viz. what are the conditions under which the product now plugging the old pipe at Kimberley became hydrated?

I must confess to being very much in the dark on this point, more especially when I remember the enormously high temperature which would be necessary to produce igneous fluidity in rocks consisting of such refractory minerals. For this reason I cannot think that the hydration was effected where we now see the rock, but that it took place lower down, and possibly long before the eruption which produced the mixture we now know as the diamond rock. All the evidence at present accessible seems to indicate that somehow or other, and possibly on several occasions within a limited period, there burst through the shales, and through the dolerites permeating the shales, a magnesian silicate with its constitutional water as a gas in a state of extreme tension, and that this material carried along with it portions of the various rocks it met with on its way upwards.

Such seems to be a not improbable account of the mode of occurrence of the singular and unique breccia, to which it would be quite impossible to assign any petrological name, and which may be described simply as the diamond rock of South Africa, being, to the best of my knowledge, entirely *sui generis*.

The possible Origin of the Diamonds.

Finally we must consider how a rock such as we know this to be, generated under conditions which we can partly understand, is likely to have been the original home where the diamond was elaborated. The undoubted facts of the case are that a mixture held in a base consisting chiefly of magnesian silicate has been forced through both dolerites and shales by an action which in a certain sense may be regarded as hydrothermal; *i.e.* to say, it has been due to the expansive power of water-gas

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acting under irresistible pressure from below, and apparently at a moderate temperature. This extraordinary flow has brought along with it and partly incorporated into itself the débris of various rocks, much of which now appears as the "floating reef" of the miners or as "pebbles." We must not suppose that this has been derived merely from the walls of the existing pipes, for it is found abundantly in the very centre of the once fluidal column, pointing to the probability of that column having passed through both shales and dolerites at greater depths.

As the depth of the mining operations at Kimberley increases we shall obtain more accurate information on these points, and possibly the ramifications of this elliptical pipe may be traced so as ultimately to set all doubts as to its origin at rest.

Meanwhile we must again ask ourselves, do the conditions, so far as we know them, appear likely to have produced the diamond *within the rock itself?* So many other crystals, such as magnetite, ilmenite, garnet, bronzite, &c. occur, some of which may have been derived from the rocks passed through, that the same origin might be claimed for the diamonds, viz. that they came, as Professor Ramsay supposed, from some metamorphic rock at a great depth below. It should be stated here that small gneissic fragments are found in the diamond rock.

In Mr. Dunn's third contribution to the Quarterly Journal of the Geological Society, he drew attention to the carbonaceous character of the shales forming the reef at Kimberley, and perhaps some persons then learnt for the first time that these black shales were carbonaceous. But nearly ten years ago Mr. Paterson* had pointed out that on one side of the Kimberley Mine were being drawn out buckets of carbonaceous shale, and on the other side buckets of green marl. He also observed that the marl or "stuff," *i.e.* the diamond rock, was richer opposite the shales. He stated that burning removed the element of blackness in the shales, and that an oily scum might be found on the water of the wells sunk in these shales.

It may perhaps be a mistake to suppose that there is any great difference in the diamond yield opposite special portions of the shales, as alleged by Mr. Dunn in his last paper, but there can be no question as to the general correctness of Mr. Paterson's statement. Unquestionably Kimberley Mine, which is largely within shale, is far richer than the others, and this circumstance does seem to point in the direction of a connection between the carbonaceous shales and the diamonds. But if the shales really have

* Proc. Geol. Assoc. Vol. III. p. 77.

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supplied the carbon, which has yielded the diamond in the manner I am about to suggest, such carbon has most probably been derived from shales occurring at greater depths. I am not aware how deep the shales are known to extend, though Mr. Oats in a very recent communication to the Geological Society* states that so far as he knows, they do not occur below 270 feet, whilst the "ground" is successfully worked for diamonds at a depth of 350 feet. Mr. Dunn's suggestion that below the shales the rock may cease to be diamantiferous was likely to cause some uneasiness, and it seems to have been Mr. Oats' object to show that there was no cause for alarm. The latter maintains that the carbonaceous shales have nothing to do with the origin of the diamonds.

It is true that certain objections to the diamond rock itself having been the birthplace of the diamonds are based upon the imperfect condition of many, I should perhaps say of most, of the crystals. The stones are often broken, as though they had been shattered by some agency; and it is said that the corresponding pieces are never found in the vicinity of the principal stone. It is not difficult to believe that the shattering is simply due to the molecular strain which is known to have caused not a few of these "dry diggings" diamonds to "explode" spontaneously after capture. Some may have exploded at the moment of birth, others according as the pressure varied in the ascending column of viscous matter. I think, therefore, the argument has weight in so far as it indicates that the stones, in the majority of cases, were not generated in the *exact spots* where they are now found. Each diamond was born lower down, and on its way upwards, if it had become broken, the pieces would be separated. Such a result is exactly what we should expect from the rise of the viscous fluid in the pipe. This view is not inconsistent with the origin of the diamond within the rock itself on the basis already suggested, provided the carbonaceous shales or similar beds occur at still lower depths. This may be taken for granted so long as pieces of the shale continue to be found in the diamond breccia.

Notwithstanding the assumption on the part of Mr. Oats, there does therefore seem a possibility that the diamonds in this rock are the result of reactions which have taken place between the hydrocarbons in these or similar shales, and the hydrous magnesian silicate under peculiar conditions of temperature and water-gas pressure.†

* Abstract 429, p. 26 (1883).

† In a recent issue of the *Chemical News* (Vol. 46, p. 105) there is a short article "On the origin and formation of the Diamond in nature." The author, who makes no allusion to the South African Diamond Rock, believes, from the analogy of silica

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The conditions under which this was effected may have been somewhat as follows:—It has long been known that water gas under great pressure and at a moderately high temperature will dissolve both silica and alumina, and that, on withdrawing the solvent or lowering its solvent action, the gaseous solution nearly always yields a crystalline solid. But note the difference between these oxides and carbon, viz. that all attempts to effect a solution of solid carbon have hitherto failed. Hence we must look for some compound of carbon which is likely to give the desired results.

Now the old chemists had suggested that the diamond was originally derived in some way from a hydrocarbon: Liebig, for instance, thought by a slow process of decomposition in a fluid rich in carbon and hydrogen. That we should look to the hydrides rather than to the oxides of carbon to provide us with the pure element, both in its amorphous and crystalline form, seems to have been the notion of most chemists: I mention this because in the discussion on the reading of Mr. Dunn's third paper before the Geological Society Professor Seeley threw out a hint that "carbonic acid might have been carried down by water and then decomposed by the heat of the volcanoes, so that the carbon, when liberated, might become crystallised." There are also other combinations of carbon which suggest themselves: for instance, in the preparation of pure amorphous carbon in organic chemistry the vapour of carbon tetrachloride is passed through a hard glass tube containing metallic sodium heated, with exclusion of air. But carbon tetrachloride savours more of the chemist's than of Nature's laboratory; I merely quote the practice as showing that the affinity of certain metals for one of the elements of a gaseous compound of carbon is, under certain conditions—one of which must always be the entire absence of free oxygen—so powerful, that the carbon, being left in the lurch as it were, and not having anything wherewith to ally itself, must needs be deposited in the solid form. I may also mention here a curious fact lately alluded to by Mr. Teall—that graphitic carbon is deposited in the cells of the slag which is derived from spiegeleisen, but not from that derived from other kinds of pig iron.

There has been so much said for and against the success of Mr. Hannay's attempts to make diamonds, that I cannot quote the case with

being so soluble in highly heated water under pressure, that the same law may apply to carbon, though he adduces no instance of carbon having been so dissolved. In this way he concludes that the diamond has been formed by the solvent action of highly heated water or water gas, aided by enormous pressure, on the carbonaceous matter of fossils contained in the sedimentary rocks, followed by slow cooling.

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absolute confidence; but there is no doubt that in all such experiments the fundamental method is to obtain nascent carbon under peculiar conditions. This is most likely to be effected in nature by the attraction of some metal for the hydrogen of a hydrocarbon, a result of the great affinity of hydrogen for the metals, and notably for *magnesium*. We were then told that when the carbon is thus set free in the presence of a stable compound containing nitrogen (the conditions being a red heat and a high pressure), the carbon is so acted on by the nitrogen compound that it is obtained in the clear and transparent form of the diamond. I admit that there is a vagueness about the latter series of reactions which is not altogether satisfactory, but in some such direction as this we may believe that chemists look for the synthesis of the diamond. Whether the result be diamond or graphite would seem to be in a great measure a question of pressure and consequent condensation.*

If we now return to the South African rock, it certainly does appear that many of the conditions of this synthesis have existed in the juxtaposition of the shales and the magnesian silicates which form so considerable a portion of that extraordinary medley. There could have been no lack of hydrocarbons, and where organic matter has decomposed there should at least be a sufficiency of compounds containing nitrogen. The reducing power of the gases resulting from the distillation of so much coaly matter would be certain to effect the reduction—if only temporary—of sufficient oxide to the metallic state, and this is what we require for decomposing a sufficient quantity of hydrocarbon in order to obtain pure nascent carbon. This element would find itself subject to enormous pressure, due to the expansive force of steam, and had no choice but to assume the crystalline form.

In concluding this brief and imperfect notice of a very interesting and much debated subject, I must admit that further evidence is greatly to be desired. In the first place, we require more accurate and less contradictory statements regarding the mode of occurrence of the Diamond Rock itself; and, secondly, we require confirmation of the actual synthesis of crystalline

* In his paper read before the Royal Society (Proc. Roy. Soc. Vol. XXX. p. 450) it appears that bone oil was the nitrogenous compound employed by Mr. Hannay in his synthesis of the diamond. The following ingredients were used:—Three grammes of metallic lithium were heated in closed tube with a mixture consisting of 90 per cent. bone oil, and 10 per cent. paraffin spirit. Bone oil, it should be remembered, is obtained by the distillation of bones and other animal matters, and contains, amongst other substances, a variable series of nitrogenised hydrocarbon compounds.

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carbon, together with some indications of the analogies and differences attendant on the genesis of graphite and of diamond. All these may be forthcoming in due course, and when they are so forthcoming it will be possible to treat the subject in a more satisfactory manner than can be done with the materials now in our possession; but according to our present lights we must regard the Diamond Rock of South Africa as a boiled plum-pudding rather than a baked one.

APPENDIX.—July 9, 1883.

The third meeting of the Central Diamond Mining Company was held at Kimberley, on May 28, 1883. There is a full report in the local papers. Not much additional information is obtained as to the nature of the Diamond Rock, though "prospecting" had been pushed as low as 530 feet on the south side of the mine. Nothing is stated as to results, but, since the chairman predicted a tremendous future for the Kimberley Mine, we may conclude that these were not unsatisfactory.

A gentleman well-known at Kimberley mentioned to me some time ago that the Diamond Rock had been proved at a depth of about 500 ft., whilst workings in open day were carried on as low as 400 ft. Between 400 ft. and 500 ft. a considerable change comes on in the character of the Diamond Rock, which is described as being more "sandy" and yet containing good diamonds at the greater depth. The "hard rock" or dolerite still continues to form the wall or reef it is presumed, and it gains more on the diamond stuff than do the shales, so that the area of the pipe contracts considerably at these depths.

The same gentleman also observed with regard to the diamonds, that they varied much in different places, each having its own style. There are no yellow diamonds in what he describes as the more "sandy stuff," but where the green breccia prevails the diamonds are often coloured.

At Bultfontein the diamonds are small, white, and striated. At Kimberley the faces of the octahedria are usually not curved. All have the little triangular marks.

When the diamonds are broken, sometimes, though rarely, the corresponding fragment has been found within a few feet.

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On the Minerals of the Rio Tinto Mines.

By J. H. Collins, F.G.S.

[Read February 15th, 1883.]

THE great pyrites masses of the Sierra Morena, of which those worked at Rio Tinto are by far the most extensive, may be briefly described as contact deposits, which differ from such as are ordinarily met with only in size; and from ordinary fissure veins only in the circumstance that the cavities in which the minerals occur are bounded by dissimilar rocks.

The deposits in question extend for more than a mile in length in a direction about 20° to the N. of W.; *i.e.* in the line of strike of the slates; they vary in width from a mere line or the filling of a joint up to more than a hundred metres, and they extend to an unknown depth. On one side they are bounded by palæozoic slates which are nearly vertical, and on the other by felspar porphyries. Three distinct lodes are known. These overlap each other somewhat "en echelon," the "valley lode" (hitherto not worked) extending farthest to the west—the "South" and "San Dionisio" lode occupying an intermediate position, and the "North lode" extending farthest to the east.

The filling of these ancient "lenticular"* cavities consists essentially of iron-pyrites, very rarely showing signs of distinct crystallisation and always more or less cupriferous. The copper occasionally exists as separate veins of yellow or grey ore, or as films of various rich cupriferous minerals lining joints in the main masses of pyrites, but usually it is disseminated throughout in almost indistinguishable particles. Other minerals occur occasionally under precisely similar conditons, as blende and galena. Both the country rocks also are found very frequently charged more or less with cupriferous pyrites; and sometimes the boundary between pyritous deposit and containing rock can only be determined by economic conditions; frequently, however, the boundary is quite sharp and distinct, especially as regards the porphyry.

The pyrites near the surface is more or less completely decomposed, yielding masses of slightly cellular but tolerably pure hematite iron ore,

* They are frequently spoken of as lenticular, but their form is far from resembling that of a lens, even in horizontal cross-section.

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and this again is capped in parts by horizontal deposits of iron ore of very similar character but of subsequent origin.*

It is not at present my intention to discuss in detail the mode of origin of these important deposits, which some have regarded as igneous eruptions, but in which I can see nothing but aqueous agency posterior to the eruption of the porphyry.

Considering the great extent of the deposits, and of the works in connection with them, the number (and variety) of the mineral species met with from time to time is extremely small. The following list includes all that I have seen or heard of on what appears to be satisfactory authority.

a. Native Elements.

Copper occurs in joints of the slate both at the south and north Lodes, according to Messrs. N. Kennedy and James Osborne. I have one specimen in which the copper occurs in very thin flakes between the laminæ of the slate, as if reduced from percolating cupreous solutions by some organic matter there present. I have also specimens of oak and firwood from the mine, given me by Mr. Osborne, in which a similar action appears to have taken place, as the tissues of the wood are permeated by metallic copper.

Sulphur occurred in 1881 in beautiful brilliant crystals, very highly modified, in cavities of the ore raised at San Dionisio and given to me by Mr. W. H. Davy and Mr. F. Johnson. The latter gentleman was the first to detect their real nature, which was by no means obvious owing to their minuteness.

b. Sulphides, &c.

Pyrites.—Usually contains from two to three per cent. of copper in an intimate state of mixture. This mineral is now being extracted at the rate of more than a million tons per annum. Crystals are rarely seen except in the slate or the porphyry, and then they are usually very small—either cubes or pentagonal dodecahedrons, or else the well-known combination of these two latter forms.

The portion of mineral which is exported, about one-third of the whole production of the mine, is neither the richest nor the poorest of the mass; these are reserved for local treatment; consequently the "export mineral,"

* For a description of some of these horizontal deposits of iron ore, see a paper by J. A. Phillips, F.R.S., *Quart. Journ. Geol. Soc.*

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while somewhat richer in copper than the average of the whole mass, is at the same time much more even in composition.*

Sulphur	48·98
Arsenic	1·00
Antimony	0·06
Copper	8·06
,, Sulphate	0·12
,, Oxide	0·50
Lead	1·47
Iron	41·91
,, Sulphate	0·50
Zinc	0·62
Cobalt	0·02
Lime	0·10
Moisture	0·65
Bismuth, Selenium, Thallium, Nickel, Silver, Gold, Silica, Alumina and loss	1·01
... ...	100·00

Silver about 1¼ ounces per ton; Gold about 10 grains.

Selected specimens of the pyrites taken from portions which are as free as possible from copper contain no more than 0·5 per cent. of copper, and scarcely anything else except sulphur and iron. The crystals from the porphyry and slate contain still less copper—sometimes no more than a trace; but I have never met with any absolutely free from copper.

Much of the export ore has a thin coating of Brochantite on it—a lining of the original joints of the pyritous mass. Without materially altering the average copper contents, this often gives special cargoes a very rich appearance which is by no means borne out by analyses.

In 1881 a quantity of dark sandy-looking material was brought up from a deep bore-hole at the "North Lode," which proved to be minute crystals of pyrites coated very thinly with galena. All the pyrites contains small quantities of silver and traces of thallium, selenium, and gold.

Chalcopyrite occurs in veins and patches in the general mass of pyrites. The finest specimens I have seen were raised from the part of

* This is an analysis of a fair sample of ore exported in 1878, made by a friend. The ore exported at present is slightly richer, but the composition of the mineral does not materially differ.

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the mine known as San Dionisio. Here it occurs in considerable quantities; I have never seen it in crystals, but I have found pieces so pure as to contain upwards of 30 per cent. of copper.

Erubescite.—This occurs occasionally in veins with the chalcopyrite. I have never seen crystals.

Chalcocite.—As erubescite.

Covellite.—Occurs occasionally as thin films lining joints in the pyrites. No crystals seen.

Melaconite.—As Covellite.

Blende.—As erubescite and chalcocite; also in small brilliant crystals at San Dionisio. Also disseminated with galena.

Galena.—Occurs massive; granular and disseminated, and occasionally in small modified cubes—the latter more frequent at San Dionisio. All the galena is more or less argentiferous, yielding a lead containing about 40 ounces of silver to the ton. In the North Lode heading a few years since some argentiferous galena was met with which contained 120 ounces of silver to the ton.

Pyrargyrite.—Occurred in a small vein which was cut in the North Lode heading about 1879, and was analysed by Mr. F. Bawden at the time.

c. Oxides.

Hematite.—Abundant as a capping several metres in depth on the hill known as Mesa de los Pinos; also on the hills known as the Cerro de los Vacas, Cerro Colorado, and Cerro Salomon. It is frequently botryoidal and beautifully iridescent, but I have never met with it in crystals.

Limonite is associated with hematite at all the localities, but seldom in large quantities or in characteristic forms.

Pyrolusite.—In bedded veins running with the strike of the rocks at Los Planes and on the Zalamea road beyond Bella-vista.

Psilomelane.—As Pyrolusite.

Wad.—As Pyrolusite. Also as small patches or "eyes" in the slates near to the veins of Pyrolusite, especially at the second-mentioned locality. It is often cobaltiferous and nickeliferous.

Quartz.—In veins almost everywhere, but not very abundant in the immediate neighbourhood of the mines, and very rarely as crystals.

Jasper.—Abundant, both green and red, in the neighbourhood of the manganese veins, but not elsewhere.

Opal.—As Müller's glass has been met with occasionally in fissures and cavities of the iron ore on the Mesa de los Pinos.

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d. Spathoids.

Barytes.—In north and south fissures crossing the South Lode between the great open-cast and San Dionisio—mostly in tabular crystals and associated with galena. Has also been met with at San Dionisio, the north lode, and on the hill above Gangosa.

Anglesite.—In brilliant crystals with galena in the Tunnel and the South Lode. Occasionally acicular according to Mr. Bawden.

Cerussite.—As Anglesite. Some needles have been seen two or more inches long.

Chessylite.—In soft clay at Los Planes. Also in fissures and cavities in decomposing clay slate.

Malachite.—As Chessylite.

Melanterite.—This is not uncommon as a secondary formation in the open spaces of the mine—a result of the decomposition of the ores. It occurs both in crystals and in stalactites. They are almost always cupriferous and zinciferous, and their composition is, as might be supposed, extremely variable. Some varieties contain more copper than iron, but all the crystals I have as yet seen, whether small or large, have the form of Melanterite, and not of Cyanosite.

Cyanosite.—This occurs occasionally in stalactitie forms, but not, I believe, in crystals.

Brochantite.—This occurs as a thin coating or film in joints of the pyrites; it sometimes exhibits crystalline facets, but I have never seen measurable crystals, and it is usually amorphous.

Chrysocolla.—This is met with under the same conditions as Brochantite, but very rarely, and in small quantity only.

Vivianite.—Occurs in brilliant dark-blue crystals in the cavities of human bones taken out of a supposed Roman well, and given to me by Mr. James Osborne in 1881. I have never seen it in ore raised from the mines.

The following have only been met with as results of the industrial operations carried on at the mines:—

Realgar.—As an incrustation on the top and upper portion of the sides of the heaps of burning mineral (teleras).

Orpiment.—As Realgar.

Arsenolite.—As Realgar; often in very beautiful octahedrons—occasionally as much as half an inch in the side.

Claudetite.—Occurs in fine pearly flakes in the "chimneys" of the "teleras," where the supply of oxygen is more limited than on the tops of the teleras. This mineral is said to have occurred in fissures

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of the pyrites at San Domingo, but nothing of the kind has ever been seen at Rio Tinto, except in connection with industrial operations (calcination of ore, &c.).

In concluding these brief notes, I have to acknowledge my obligations to the following members of the Rio Tinto staff for information given at various times on this subject, viz. Messrs. N. Kennedy, Jas. Osborne, F. Bawden, H. B. Fulton, F. Johnson, W. H. Davy, and John James.

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The Geognosy and Mineralogy of Scotland.

By Professor Heddle.

SUTHERLAND.—Part V.

The "Igneous" Rocks Continued.

THE granite of the Ord forms one, and that probably the smallest of a number of masses which constitute the border-land between Caithness and Sutherland. The features of this granite vary considerably at different points. It will, however, be afterwards shown that the rock is possibly continuous from north to south,—that is, from Sandside Bay, on the Pentland Firth, to Navidale, near Helmsdale.

The question as to whether any part of this granite is igneous, in the sense of being eruptive, or indeed in any sense, is best deferred until a consideration of the same point as regards the syenite of Ben Loyal has been entered upon,—the evidence as regards this last mass being every way clearer, and the locality more accessible. I owe it to Mr. Mitchell, of Ribigill, that I have lately been enabled again to take up this point. Through his courtesy and scientific enthusiasm, I have, in company with Mr. John Gunn of Dale, thoroughly examined the hill and surrounding district, in circumstances of such exceptional comfort that the minutest points could be attended to in detail. Either now or on former occasions each individual aiguille has been ascended, and the section on its scalped front examined; while, with the exception of a mile of grassy slope, the hill itself has been walked round.

There is no hill in Scotland, not even Arthur's Seat or North Berwick Law, which conveys to the eye so decided an impression of its having burst through an overlying crust, and thrust its spire-like summit aloft while it was in a plastic condition. This perhaps should not be said of the hill itself, except when viewed from the north; but the isolated aiguilles which cluster round the central and more massive height, convey that impression much more emphatically than could any single cone even of steeper angles, (though it is doubtful if angles higher than those here seen could be compatible with stability).

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Notwithstanding this extremely volcanic appearance, the hill seems to have been little visited; and a locality which should have been regarded as a fruitful field of information as to the operations of old igneous action, seems to have been reported on by Murchison and Cunningham alone.

The views of the former regarding it are precise, positive, and well-known; they are to be found scattered sparsely through the various papers he has published on the district, and may be said to be summarised and emphasised in the general section he gives of Sutherland, where the hill is figured protruding as an eruptive mass, which throws the ruptured rocks at high angles off from its eastern and western flanks.

The views entertained by Cunningham are, as is usual with that writer, enunciated with more caution; and there is this rare value to be attached to them, that, as he himself puts it,—"I have never made a statement on any other than my own individual examination."

The following condensation of Cunningham's observations is inserted, in order that some justice and some deference may be paid to one who commences his work by writing—"Love of theory, rather than love of examining, has so disseminated itself among geologists, that the greatest opprobrium which those ignorant of geology can cast upon it is found in their merely rehearsing a catalogue of the theoretical hallucinations which an inattention to anything like inductive philosophy has so prolifically generated"—who concludes it by writing,—"I have never been influenced by that baneful love of controversy which is far from rare in scientific discussions,"—and who throughout his essay has shown himself to be singularly free from both weaknesses, observing with a single eye to the recording of facts, and annotating in the true spirit of a *student* of nature.

Cunningham writes:—

"There are two districts in which syenite, a rock very generally associated with granite, and only differing from it by a mineralogical accident,* is most abundant—the mountain of Ben Laoghal and a tract of country near Lairg.

"The syenite of Laoghal consists of a light flesh-red felspar, grey quartz, and dark hornblende; sometimes the quartz almost disappears, the rock then becoming a binary compound of felspar and hornblende. On the large scale this syenite is disposed in a most distinctly tabular manner. From various parts of the summit the entire structure of the mountain may be traced with the utmost precision, and the several tabular concretions followed throughout its whole extent. In thickness these masses vary from a size recognisable in

* "The result of an examination of their connections is that the formation of both rocks is similar, and that they are to be considered merely as modifications of each other."

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a hand specimen, to others of a magnitude so immense that they can only be examined in the district. The lateral planes of the tabular concretions are, in general, nearly parallel, and exhibit an almost polished surface

"I shall next proceed to detail the associations of the true crystalline stratified rocks with the granites and syenites—geognostical phenomena that can never be too strictly investigated, bearing, as they do, both on the chemical and mineralogical department of the science.

"It is found that the simplest mode in which the two series are connected, is that in which the granite forms *imbedded masses* in the gneiss. It may be stated that no gneiss (the components of which are large) can be discovered in which these components are not, in greater or less quantities, so arranged in some parts of the stratum as to be a granite in the strictest mineralogical sense.

"Another relation which must be attended to is the appearance which exists *at the plane of contact*. The result of an examination of many hundreds of these over Sutherland is, that no definite line of boundary is visible when the rock is unweathered; but on the contrary the minerals of both masses interlace each other intimately, so that it is impossible to discover where the one begins and the other ends.

"In some instances the gneiss exhibits an almost complete transition of one or more parts of a stratum into a nearly perfect granite; into a rock which indeed, in a mere hand specimen, is such. The only mark by which to distinguish on the large scale this gneiss from undoubted granite, is in there being usually a possibility of detecting in it a certain series of parallelly-disposed bands of micaceous scales.

"On entering upon the examination of the gneiss of Sutherland at a distance from granite, either in veins or in large bodies, the first appearance which attracts attention is the general dip of the strata to one point of the compass, or, if this is reversed, a sameness in their direction. Advancing to the vicinity of a granite group, before arriving at the main mass of the rock, a district is invariably found which is traversed so abundantly by granitic or syenitic veins, that it is often difficult to determine whether the granite, syenite, or gneiss, prevails most. The district so constituted, too, is not of limited extent, but occupies miles of country; the direction of the strata, however, will be found to be the same as that which was observable in quarters where there was neither granite nor syenite. The veins pass through the strata without causing disturbance, and the same strata meet the principal formations of granite without their positions being changed. If, when at a distance from the granite, they are inclined against it, when in contact with it they are the same; and, on the contrary, if, when far removed from it, they are so disposed that if they were extended downwards they would sink under the granite, so, when in actual junction, the same position is apparent. Frequently, when examining the more central parts of the granitic or syenitic nuclei, large enveloped masses of the neighbouring stratified rocks may be

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detected; the laminæ of all these, however, will be found to have the same direction and dip as the several laminæ which compose the great body of the Neptunian deposit. The position of the strata, however, as being not affected by the presence of granite (if these strata are examined all round the granitic mass), becomes still more conclusive and remarkable, as the very same appearances, in regard to mineral and positional character, are found to exist over every part of the stratified system, which is extended for miles round the granite."

The most prominent statement of fact here is, "the strata meet the principal formations of granite without their position being changed;—if when far removed from it they are so disposed that were they extended downwards they would sink under the granite, so, when in actual junction, the same position is apparent."

Perplexed by such absolute discordance as to facts, I commenced the examination of the district by making two traverses to determine what was the disposition of the rocks *when far removed* from the granite. Though Murchison and Cunningham seem here to be much in accord,—the former figuring an easterly, the latter a south-easterly dip,—still I conceived it well to make assurance trebly sure.

The first of these traverses, made in a previous year, was commenced at a height of 2,250 feet above the fork of the Allt-na-Cailleach on the south slopes of Ben Hope,—a spot passed over some years ago by Mr. Dudgeon and myself. Having thus connected the line with a previous traverse, I held across the moor as directly at right angles to the strike as the ground permitted. This line I found carried me past the north end of Loch-na-Meide, over the north shoulder of Cnoc-au-Daimh Mohr, and joined the Altnaharrow road near Loch Buidhe.

In our previous traverse we had found the mica schists of Ben Hope dipping E.S.E. In some cliffs on the S.E. shoulder of the main hill, I saw some indications of a shallow trough on that slope; while away to the S.S.W. there appeared to be a local anticline at the summit of Cnoc-na-Togaile. At every spot, however, that my foot passed over, the rock, at dips varying from 15° to 20°, fell to the S.E. and E.S.E.

For the greater part of the way to Loch-na-Meide, glaciation from the west rounded the numerous outcrops, and disclosed the gradual passage of the dark flaggy schist into more silicious and gneissic layers. The central portion of the ground is obscured by vegetation, but, in passing over the more southern, innumerable outcrops, like interminable waves of the sea, become wearisome to body and mind alike.

Continuing the section by a second traverse from Altnaharrow over Ben Cleith-bric (*Klibreck*), the beds—somewhat more gneissic—are found

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near Loch Naver still dipping the same way, but at an angle of about 25°. This rises, in the steep and rocky face of the hill, to nearly 50°; while its 3,000 feet of altitude, added to the twelve miles previously gone over, vouches for an enormous thickness of rock, laid down with scarce a wrinkle.

This continuously unwrinkled floor is in strong contrast with the section at Strath Oykell on the one hand, where, between Oykell Bridge and Rosehall, five synclines and four anticlines may be seen, and the northern section between Scullomie and Melvich, on the other, where, though the prevailing fall is to the east, great and tumultuous fracturing, with rocky knolls, is the chief feature.

The impression conveyed is altogether against the probability of the northern mass of syenite being metamorphic, unless something very different in the nature of the rocks, and in the circumstances in which they are placed, should there obtain.

The starting point of the second traverse was separated from that of the first by about half a mile; the line was from the south shore of Loch a Ghobha Dhuidh to Ribigill, being nearly at right angles to the first.

Except that the dip swings round somewhat more to the east, and that the angle of the dip is somewhat greater, there is in the western portion of this traverse nothing different from the first. At the Carn a Mhadaidh, however, there is a marked change. The eastern frontlet of this hillock has been torn off and hurled eastward,—possibly by ice;—and its shattered masses show a great hornblendic change in the nature of the rock. Eastward of this it is again mica gneiss; but still further eastward, where the cuttings of the new bridle-path lay the beds freshly bare, first hornblende-slate with garnets, succeeded by mica gneiss, and that by chlorite or ripidolite slate, are seen alternating. A very felspathic grit appears at Carn Fada, and this, above Ribigill, gives place to ordinary mica gneiss and hornblende-slate. The dip of the whole series is persistently towards Ben Loyal, but in this traverse it varies, ranging from 15° to 45°. At the rock-exposure which in this line is nearest to the east end of the north face of the hill,—namely a knoll directly N. of Canaisaite,—a gneissic flag with a black mica, dips S. by E. (mag.) at 40° to 45°.

North of Clach-an-Armuinn, and opposite the western end of the same face, there protrudes out of a morass a mass of *serpentine*, the original gneissic structure of which is admirably disclosed by parallel undulating layers of scaly talc. Two beds of this rock are seen dipping under Loyal at about 20°.

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This second traverse has thus shown that there is this marked difference in the rocks in the more immediate neighbourhood of Loyal as contrasted with those further south and more distant from the hill, that there is considerable variation instead of marked sameness in the nature of the rocks themselves. It must also be said that they are, on the whole, somewhat more alkaline. The circumstances in which they are placed, however, seem, up to this point, to differ to an inappreciable extent.

The structure of the hill itself has now to be considered.

From the vicinity of Clach-an-Armuinn, indeed from many points to the north-west, it is clearly seen that the whole of the lower portion of Ben Loyal consists of gneissic rocks, which form a plateau protruding beyond the syenitic superstructure, to east, to north, and markedly to the west. This plateau is most evident along the north face, and the north-west angle. At the western foot of Sgor-a Chonais-aite the height of this plateau is about 880 feet above the sea, while it reaches to near 1,000 at Creag-an-Dithreibh,—the whole mass of which is gneiss. Under Creag-an-Speireig on the east of Ben Hiel the plateau is less well seen, and has fallen to a height of about 530 feet; while at Beinn Eudainn on the south, it protrudes from under the syenite at a height of about 650. Along the north face of the hill this projecting hill-foot presents a steep and craggy frontlet, for the most part birch clad. Everywhere the strata composing it dip into the hill, plunging under the syenite about S.S.E. (mag.), at slightly higher angles than the average of those of the rocks mentioned in the last section.

The beds on the south side of the hill issue from under the syenite with a dip towards the same point of the compass.

The syenite is disposed upon this gneissic plateau as a central dome with castellated summit, which throws out protruding spurs terminating in four sharp peaks. The hill thus, when viewed from the north, bears a resemblance to the knuckles of a clenched hand.

At the delta of a stream which has cut a gash in the face of the eastern peak,—Sgor-a-Chonais-aite,—flaggy micaceous gneiss of a pale green colour is seen dipping into the hill at an angle of 23°. In its greenish or yellowish white colour this rock bears some resemblance to the *sericite-schiefer* of Hellgarten and Nerothal. It is, however, devoid of its silky lustre, and is much more fissile. The beds of this gneiss are cut diagonally by veins of white oligoclase (?) and also by thin layers of a pale greenish yellow schist. Some little way above, veins of red syenite, with a distinctly laminated arrangement of its mica, cut the flags. These veins often insinuate themselves between the laminæ of the flags.

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Veins also of coarse-grained granitic structure occur. These contain a highly lustrous felspar, which shows no knitted structure, but contains a chloritic substance, and *ilmenite*. A few feet above this a peculiar black hornblendic rock occurs. For about 70 ft. the section is now concealed by debris; then the micaceous green flags are again seen, but with an increase in the number of the granitic veins, which here ramify to a greater extent, but show everywhere a tendency, more or less marked, to follow the bedding of the flags. This is evidenced by the fact that when in ramifying they cut through the flag layers, they almost immediately bend to follow the lines of its bedding, and, sooner or later, their flexures again cut the layers and return to the parent stem. Where this feature is seen the flaggy rock is markedly less micaceous. There is at this point, indeed, but little of either hornblende or mica to be seen in either the granitic veins or in the general mass of bedded rock. The veins consist of little else than quartz and pink felspar, and the foliation of the rock itself is disclosed merely through a darker or lighter tint in the zonation.

Above this point the solid rock is concealed by an enormous talus of debris. When the syenite is itself reached at the foot of the cliff, its almost erect exposed surface presents at first sight an appearance very similar to ripple-marking. On examination this is found to be due to a laminated structure which perfectly accords in strike and apparently in dip with that of the underlying rock.

The syenite is disposed in enormous slabs many hundred feet in dimensions; these droop in huge but gentle curves from the summit or from overhanging bosses of the hill.

The main jointing of these slabs is at right angles to the structure which has been described (and which would be taken as the original bedding of the rock by those who hold it to be of metamorphic origin).

To the general dip of the rock being here about 20°, and to the jointing hence departing from the vertical to only a similar extent, and also to its being very open, is to be assigned the great precipitousness of the cliff, and the apparent feeble hold which these enormous slabs have of the face of the precipice.

It may be scaled diagonally along some grass slopes, and the rock where freshly exposed is seen occasionally to contain imbedded and often dislocated bands of laminated or chloritic rock. The direction of the lamination accords with the strike of the underlying rock. Fragmentary portions are also seen imbedded, though very rarely, and the softened or diffused character of the crystalline constituents which form the edges of these certainly conveys more the impression that this is a rock in the

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last stage of metamorphic change, than of its being one in which mere fragments have been caught up and impacted in an igneous outburst.

At the N.N.W. foot of this great slab-sheathed precipice, and at a height of about 790 feet, the same schistose gneiss is seen, but here the dip is considerably higher. Its features are the same as those assigned to it at the first locality, only perhaps there is somewhat more condensation in space as regards its assumption of a granitic structure. The last true gneissic bed is also somewhat more convoluted, and apparently more hornblendic. Syenite, perfect in its structure, succeeds directly to the hornblendic bed, and with a sharp and close fitting junction. The syenite itself occurs in well marked beds, of about 5 ft. in thickness. Weathering discloses in these a laminated structure, perfectly similar though hardly so minute as that seen in the gneissic beds. The strike and dip both of these laminæ and of the beds themselves are identical with that of the gneiss. The laminated structure is better disclosed as we continue to rise. These lower beds of syenite are succeeded by gneissic beds of about 80 ft. in thickness. They are seamed, nearly horizontally, by pale granitic belts.

Immediately above the gneissic beds a boss of syenite appears of a much more massive description than that seen below.

At first sight this boss seems to be formed of beds of about 10 ft. in thickness, which appear to roll over both to the N.N.W. and the N.N.E.; weathering again, however, discloses the same lamination noticed below, while a dip in the previously noted direction is still apparent; so that the division of the rock into the huge blocks which simulate beds with a roll over is, in all probability, the outcome of a jointing similar to that seen in basaltic columns, and results from the rending associated with the consolidation of a semi-fluid mass.

At a height of about 1,450 ft. on the north-west shoulder of the spur which runs north from The Castle, the face of the cliff shows beds of micaceous schist, gneiss, hornblendic and granitic beds,—all *overlying* the syenitic beds last noticed. Here the syenite both below and above these beds still shows the same foliation developed by exposure, and the dip is the same. Of the beds of a schistose nature it has to be expressly noted that they can hardly be said to exhibit a greater extent of those appearances which have been assigned to metamorphic action, than do similar beds occurring at a distance from the syenite.

Viewed from the north peak of Sgor-a-Chleirich the syenite of the whole hill top in all its peaks is seen to be divided into great flat nearly vertical slabs of ever-varying thickness. The rents which form these slabs pass from peak to peak, so that the shorn-off ends of the pseudo-beds of the one

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peak are repeated most perfectly both in thickness and in disposition by those of the opposite peak.

The impression conveyed is that the intervening valleys had been scooped by denudation subsequently to the period when the hill as a great solid mass had been jointed or disjointed into these enormous sheets of rock.

In the col which lies between Sgor-a-Chleirich and the central dome of the hill the syenite very distinctly shows the true bedding of the rock, which here dips 29° south by east (mag.); and, that the appearance of vertical bedding is merely the outcome of a highly developed system of jointing, is at this spot very evident.

Again, on the ridge which connects the central dome with The Castle, a number of cromlech-like blocks are seen which admirably display the same original bedding of the rock.

Creag an Dithreibh, which rises with some 700 ft. of ribbed cliffs out of the lake of the same name, and which has a flat summit a square mile in extent, is entirely composed of gneiss dipping under the hill, or, more precisely, under the detached Sgor Dhu. The Creag itself is merely a semi-detached portion of the basement plateau.

The gneissic beds, however, are found on the western side of Sgor Dhu above the summit level of the Creag, up to a total height of about 1,800 ft. They are in two thick series of beds, the higher of which is somewhat more quartzose than usual. The dip throughout is the same. The junction with the syenite is not here seen, there being 10 feet of intervening cover. The first syenite seen shows no bedding, its dominant jointing being almost vertical, and agreeing in its strike with that of the jointing of the rest of the hill. As we ascend the Sgor, the syenite is found to be distinctly bedded, and to have a fissile structure alternately thick and thin, and again conformable with the bedding of the gneiss.

These fissile beds appear from this point to extend over the western slopes of the two southern summits of the hill.

An excessively massive and lofty cliff overhangs Loch an t'Sionnaich from the west side of Sgor-a-Chleirich. A very massive bed at the N.W. foot of this lofty rock, shows a laminated structure, which structure has a N.W. by N. strike, with a dip of about 30° to the S.W. by S. At one spot a slab-jointing of the syenite of Sgor Dhu is seen to dip in the opposite direction. Loch an t'Sionnaich lies in a trough between these dips. This is the only fact which is in disaccord with all the others.

I have said that where the syenite is seen to overlie the gneiss, the contact was close; the surfaces also were even; and in no spot did I see any

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vein to issue from the syenite. At several spots imbedded "neres" were seen in the syenite; very seldom were the gneissic layers of these neres removed from a horizontal position, and in no one case had the neres sharp angles.

Such are the facts which I have to adduce bearing upon the question of the eruptive origin of this syenite.

It is to be observed, in the first place, that every single observation is opposed to Murchison's views. The strike continues unaffected by the presence of the syenite,—under this the rocks pass,—and the dips are not affected at any one spot where the gneiss is in contact with the syenite.

The successive interbedding, for so many hundred feet, with gneissic, hornblendic, and micaceous layers, almost as positively negatives the view that the syenite can have been poured over the rocks, as a great cake, from some central vent.

Cunningham, distracted only by Neptunism and Plutonism, writes:—"The period when the geologist may frame an untangible theory in regard to these ancient rocks, is not yet arrived; nor will it until they are more accurately studied in their mineralogical features, and examined without any relation to an existing belief. Plutonism, expressive as it often is of vague and loose research, is too implicitly relied on, and made in many instances to explain appearances which are inexplicable by it or perhaps by any known process. It is not my intention to add in regard to granite another theoretical crudity to the many already belonging to the imaginative department of geology. The fact, however, is apparent that granite is in its nature intimately connected with gneiss, and that perhaps it may be considered more as a modification of it than a distinct rock."

Metamorphism was not then even in the nursery of "known processes," and never did it seem to the writer to come so absolutely within the category of theoretical crudities as when he attempted to apply it to the explanation of the formation of this syenite, in the light of the circumstances which here obtain.

Can metamorphism suffice to explain continuous and perfect transmutation on one side of a knife-edge line,—a bedded unaltered rock lying in contact on the other side, and even sometimes in the midst of the rock held to be transmuted? and where lie, unaltered, the two thousand feet of highly alkaline or felspathic beds, the representatives of which in a granitic form are now reared aloft on a pedestal of near 1,000 feet in height? The dip of even the highest beds on Ben Hope would carry them down probably

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as low as the plateau of Ben Loyal; so that, if the syenite of its aiguilles represents any bedded rock, such rock must have been higher in the series than the flags of Ben Hope. The upper beds of Ben Klibreck occupy such a position, but these are far from being so felspathic as to be convertible into syenite.

Tried by the touchstone of such circumstances as these, it is impressed upon us how much as yet "metamorphism" is "expressive of vague and loose research,"—how often it is relied on "to explain appearances, perhaps inexplicable by any known process."

It is clearly our present duty to render our existing theories of rocks more unassailable ("untangible,"—Cunningham,) by a more and more accurate study of their mineralogical features;—and to have as little to do as possible with "the imaginative departments of geology." Assuredly if the changes assigned to metamorphism be not more sedulously studied both in the field and in the laboratory, it must be relegated to the category of what Robert Dick calls "fashionable speculative dreams." At present it is little better than the shibboleth of the superficialist.

Minerals of the Gneiss.

The first mineral I have to notice as found during these recent traverses is *red avanturine*. This occurs possibly as an accidental transmutation or alteration of a very quartzose mica-schist, where the latter is passing over almost into a quartz rock. It is to be found near the shores of the Gorm Loch under the east shoulder of Ben Hope. The specimens are moderately fissile, and from the brilliant red tint of the imbedded mineral which gives the colour, and the high lustre of the mica which produces the spangling, they are very striking in appearance. To the microscope this imbedded mineral does not present the appearance of a mica, or any foliated structure;—its form being that of elongated masses like grains of rice. These grains have a fine amber or a ruby-red colour; they more resemble augite in form than any commonly occurring mineral, and are not to the smallest extent dichroic.

The eastern frontlet of Cairn-a-Mhadaidh, noticed above, presents an extraordinary scene of ruin and rock dislodgment. That portion which had apparently been the original summit has been rent from its attachment, and slid downwards, hurling vast masses before it, so that, for several hundred feet of altitude, there is a labyrinth of countless blocks which is rendered more involved from the comminuted rock giving sustenance to a grove of birch.

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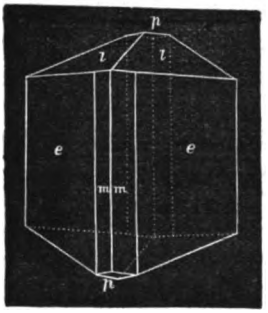
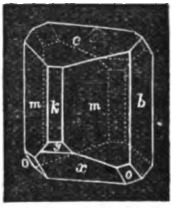
The rock is here commencing to be hornblendic, and is passing into a laminated arrangement of red felspar and matted actynolite. A few minutes' search showed occasional flat cavities in the layers, which contained *rock crystal*, *hornblende*, *sphene*, and *orthoclase*.

The rock crystal was in its usual form.



Well-crystallised *hornblende* is exceedingly rare in Scotland. I do not remember better than that here seen. The crystals are generally of the actinolitic type (see fig.), in radiating brushes which extrude their free terminations from their matrix of felspar. This, apparently solely *orthoclase*, is in the annexed form.

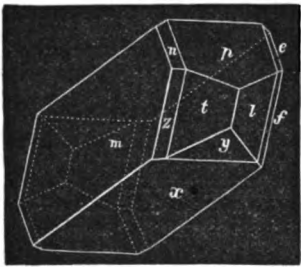


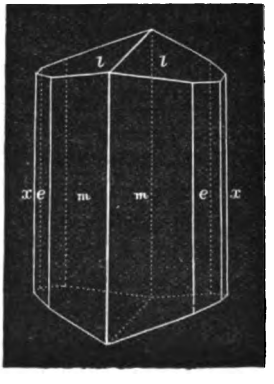
The *sphene* is in crystals of about the size of split peas, and is both pale yellow and dark brown. It is in the forms numbered 1 and 4 of the Shinness crystals.

The beds of hornblende-slate come in on the south-eastern flanks of Meallan-Liath; the imbedded *garnets*—much flawed—are in rhombic-dodecahedra.

Still further east are beds of foliaceous *ripidolite* (?), containing loosely imbedded *garnets* of the same form, and with edges sometimes truncated. These are smooth-faced, lustrous, and somewhat transparent.

A quarry hole on the road above Ribigill shows hornblendic beds, cavities in which have much the same assortment of minerals





as those seen at Cairn-a-Mhadaidh, but contain also *albite* in the form *m*, *p*, *t*, *l*, *n*, *z*, *e*, *f*, *y*, *x*, more elongated along *m* than in the annexed figure.

The *hornblende* is in the form drawn.

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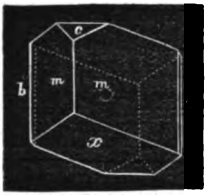
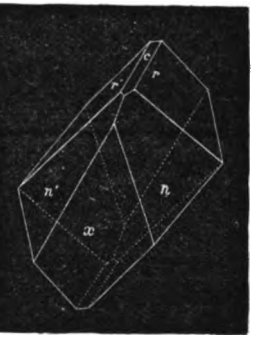


The felspar as in the figure.

The hornblendic beds sometimes contain bands of lustrous pale green *byssolite*, which has a slightly waved but parallel arrangement of the fibres.

Sphenes occur in the form figured, and also with *c* truncating deeply; they are rare.



Minerals of the Syenite.

I have elsewhere alluded to the disadvantage at which the collector of minerals is placed, in comparison with gleaners in other departments of natural history;—how dependent he is upon the operations of force in its various forms to lay bare and dislodge the objects of his search. I spoke of the aid afforded to him by the breaching power of sea waves, or the elevating force of earthquake throes. The turmoil at Cairn-a-Mhadaidh suggests another,—the direct, continuous, and ultimately prevailing operation of gravity, where precipitous slopes admit of its acting as a rending power. Another agent,—the force of running waters,—the operations of a "waterspout," does not so readily suggest itself, yet to this, though here operating only once in a century, are we indebted for laying bare the chief treasures of the syenite of Ben Loyal, and for establishing to a great extent the direction of the ice flow in the district.*

In the description of the great boulder which lay upon the west slopes of Ben Bhreck, it was pointed out that in all probability it had been *ice carried* from the opposite cliffs of Ben Loyal;—an inference exceedingly repulsive to the views of those geologists who hold that the ice swept over the north of Scotland from the Baltic, the North Sea, and the South-east. The finding by Mr. Mitchell of the piece of amazonstone which he sent to Dr. Joass,* was a step in the determining this question, and in order to ascertain the circumstances of that find, the writer was induced with all haste to return to the locality.

A summer's shower of but two hours' duration, but of unprecedented violence, had burst with concentrated force upon the northern frontlet of Ben Loyal, (in fact it burst nowhere else). The deluge had, by the

* Foot note, page 178.

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action of a water-wedge, torn slabs of rock from the great cliffs, and had cut great trenches in the talus at their foot; which talus had lain undisturbed so long that it was everywhere turf-covered and swathed in birch.

Here was a rare opportunity for the mineralogist.

Masses of rock which had hammered themselves against each other after plunging through the air for some hundred feet, and gashes out of which the torrent had tossed up the debris of former falls, to a depth of fifteen feet and for a length of half-a-mile.

I have described the section laid bare in more than one of these gashes; the minerals found were got almost entirely from that which scars the great cliff on its western fringes.

While desirous to find *amazonstone in situ*, and so definitely to connect the Ben Bhreck boulder with the hill, the writer was above all anxious to find the *thorite* in quantity sufficient to enable him to analyse it.

Three blocks only were found which contained veins with amazonstone. One appeared to be an old block disinterred,—a second was a fresh new-fallen mass,—the third was doubtful. Though only three blocks showed veins with *green* felspar, several others carried veins in which the felspar showed the same structure as does the amazonstone, but from which the green colour seemed to have been bleached.

It has in this connection to be remembered that exposure to *light* exalts the colour of amazonstone; and that a mantle of peat *bleaches* almost all rocks, and that turf, to a certain extent, effects the same change. The cliffs of Ben Loyal "weather" purple; those portions from which the mantle of turf has lately been skinned off, are as white as paper.

Almost all of the blocks which had these exfiltration veins of bleached amazonstone carried *thorite*, but usually in particles too small to be broken up with advantage in collecting it. Next to the felspar and greasy looking quartz, the thorite is the most frequently occurring substance in the veins; *magnetite* is next in frequency. The two latter may be distinguished by the conchoidal fracture, pitchy lustre, and dark brown to clove colour of the one,—and the magnetism, the flat or the hackly fracture, and the blue-black colour of the other. The magnetite sometimes contains specks of the *thorite*, which when broken appears red-brown or yellow. Occasionally there are traces of crystallisation in the thorite, the surface of which is then dull, pitted, and light brown. On fracture the brilliant-lustre appears, so that the surface may be altered.

Such is the appearance of the specimens which contain particles of the thorite of the size of shot.

Occasionally these specimens contain *Babingtonite*, and the specimens

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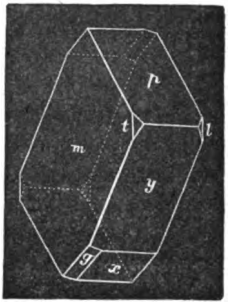
of this mineral are much superior to those found in the boulder at Ben Bhreck. The imbedded crystals are one to two inches long; when broken they show a facile lustrous cleavage, which runs along the length of the crystal. They are bright green, but are unfitted for analysis on account of being pervaded by plates of brown mica. Such crystals are quite thin. Others, fortuitously broken transversely, show several faces; but the number of specimens obtained was not sufficient for ascertaining the position of these.

The forms of the *amazonstone* are those of the first type of the Ben Bhreck boulder. As the veins here found were never above three inches in width, the crystals are small, and they are almost always altogether imbedded. Small cavities sometimes contain crystals of form *m*, *b*, *c*, *x*, *o*; and these sometimes carry on their surfaces small crystals of albite of the form drawn.



One mass, which had fallen with such force as to throw the fragments of amazonstone out of the trench on to the sward, contained a jet black lustrous mineral, with a hackly fracture.

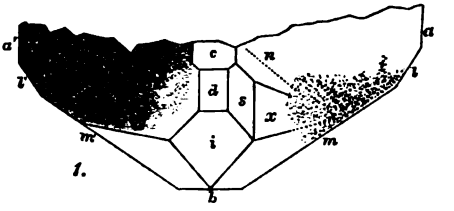
Being only partially soluble in chlor-hydric acid, it cannot be thorite. It is also harder, and of lower specific gravity.

This was disposed between the crystals of amazonstone; it showed portions of broken crystals of its own substance.

The patches of this mineral, though thin and much spread out, are two inches long and broad. Possibly the fragments obtained may suffice for analysis.

The other specimens contained comparatively little thorite, but one carries fine *topaz* in the four forms figured.

These topazes are of an entirely different cast from those many years



ago found in the Grampians, but are somewhat similar to those from the Urals. The blow has dislodged most of them from the stone, so that

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only their casts remain. The largest remaining is a broken crystal $1\frac{1}{2} \times \frac{3}{8}$ inch; the largest perfect crystal is $\frac{1}{4} \times \frac{1}{8}$. They are exceedingly brilliant, and of perfect polish; colourless to pale yellow. About one half of the length of some of the crystals is pervaded, apparently in rents, by *rubinglimmer*, so as to give that termination a red purple tint.

For some time I was doubtful as to these crystals being topaz, and for the following reasons:—

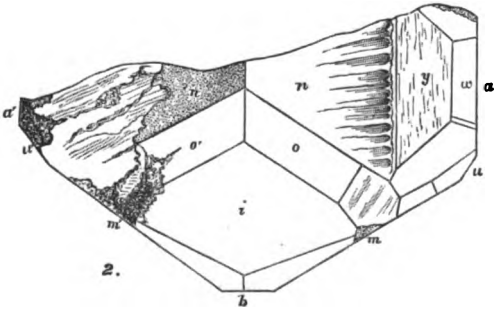
I could see no striation on any face,—I could see no trace of the dominant cleavage of topaz,—and, lastly, every one of the larger crystals shows the macropinacoid brilliantly developed. This is a face given neither by Descloiseaux, Kokscharov, or Miller, as occurring in topaz.

The imperfect traces of cleavage seen are prismatic, and are parallel to *l*, and to the brachypinacoid.

Upon applying force to the broken crystal, however, the summit cleavage appeared; and the application of the contact goniometer to those crystals which project sufficiently for its application, showed that much of the peculiar appearance was due to the prisms lying on their sides in such a position as to show the face *b* uppermost. It is largely due also, however, to the brachypinacoid being sometimes the most highly-developed face.

All the crystals have the prismatic faces brilliant and smooth, but the pyramidal faces are rough or uneven; still it would appear that in addition to *b* there are other new faces on these crystals.

The felspar alone has been protero-genetic to the topaz here; the crystals of the latter being disposed on the former. The quartz again is moulded over both. The paragenetic formation of this last mineral cannot thus have in any way impressed false faces on the topaz; indeed, these apparently new faces reflect a flash of light from a *level* though not a smooth surface.



In the figures, I have delineated merely what can be seen of each

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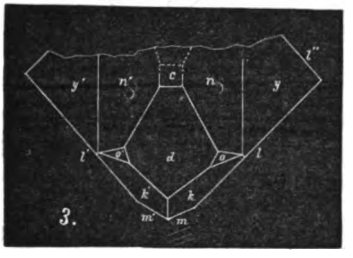
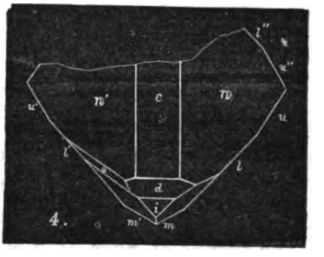
crystal; as I have detached none from the rock, the lettering is conjectural as regards the summit planes; and from the distorted view which can alone be obtained the drawings are doubtless incorrect.

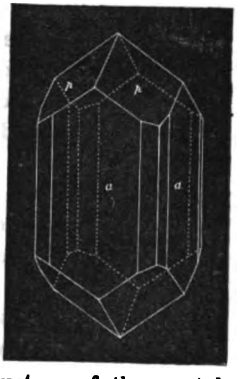
As regards the prismatic faces, the contact goniometer gave *a* on *b* 90°; *a* on *m* about 117° 30′; *a* on *u* about 147° 30′; and *u* on *u* about 115° 30′,—on two of the crystals.

The larger crystals are hemihedrally developed in their accuminating planes, but some minute crystals are less so.

The first two figures represent the terminations of two of the larger crystals; two of a cluster of small crystals are figured below.







I am much perplexed by the crystals of thorite which are found here; the figure shows one of the crystals. This accords with the form of those from Ben Bhreck, but there are also two distinct *octahedra* half the size of peas. The form seems the *regular* octahedron. The fracture both of the pyramidal and of the octahedral crystals is conchoidal, the lustre pitchy, and the colour deep brown. In addition to their being non-magnetic, there is no risk of here mistaking magnetite for whatever mineral these octahedra may be, as the magnetite here is blue-black, with distinct cleavage and hackly fracture. But the internal structure of the crystals which occur in these two irreconcilable forms is no more like that of a pseudomorph in the one case than in the other.

Of course it is mere guesswork to say that the one may be *pyrochlore*. I have not enough for any test, and the crystals are much too minute for estimating the hardness on. The pyramidal mineral is soluble in chlorhydric acid, with separation of silica; and the orange-coloured solution gives a copious ruddy precipitate with ammonia.

The magnetite is in minute octahedra and rhombic dodecahedra. The

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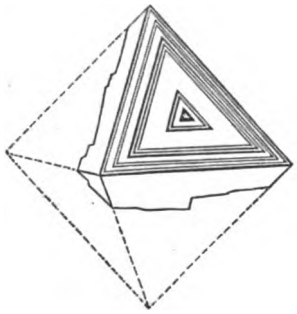
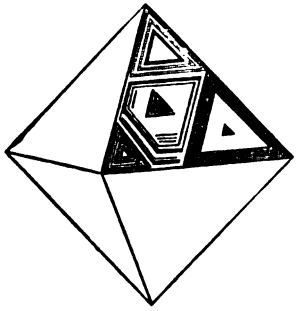
crystals of the first form show the irregularities of surface shown in the following figures.





Rubin-glimmer here and there lines cavities; it also pervades a granular felspar which forms the roots of the larger crystals, so as to give it a certain amount of "sonnenstein" appearance. Galena in small specks is the only substance found here which did not occur in the more ample veins of the Ben Bhreck boulder.

The syenite of Sgor Dhu is of a redder tint, and is also more hornblendic than that of the rest of the hill. It contains *sphenes* in well-developed but simple crystals.

The beds of serpentine noted as found in the swamp at the N.W. foot of the hill are of much interest. Mr. Mitchell had noticed many blocks of a partly-weathered rock lying in the vicinity,—and only in the vicinity of Ribigill. He was so struck with its appearance that he had it cut into ornaments; but the peculiar appearance of the stone is in these much marred by partial decomposition.

This bed of serpentine is their source—and the easterly carry of the ice is again vouched for by these loose blocks.

In the beds themselves the decomposition has penetrated to less than half an inch; and the rock itself is seen to be a dark-green oily serpentine, very uniform in its general granular structure. But it is pervaded by scales of *talc*, which are dispersed *firstly* in continuous belts of varying closeness to one another, and *secondly* in isolated rosette crystallisations.

As the rock takes a high polish and is deep in colour, and as the talc is high in lustre and silvery white, unweathered blocks cannot but form a highly ornamental stone,—the glancing scales being sprinkled throughout it in all positions.

I know of no serpentine the appearance of which is more unusual, and its appearance under the microscope is unusual likewise.

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It shows like a mass of smashed up olivine; there is no appearance of serpentinic change, the sharp-angled fragments polarising like olivine with a flat field of uniform colour, and lying in immediate contact with each other, with no intervening coating or layer of serpentine.

Still the rock weathers brown, like serpentine; and bruises with the blow of a hammer, without any splintering.

There are certain of the rocks noted above, the microscopical appearances of which call for some short notice.

The first of these is the hornblendic schist, carrying garnets, which occurs on the south-east shoulder of Meallan Liath.

The characteristic structure of this rock is—like that of many others—only disclosed by what may be called macroscopic sectioning, in contradistinction to rock-slicing for the microscope.

A slice, the size of an ordinary "hand specimen," is obtained by the use of the "diamond slitter." If the plate has cut flat and fair, all that is necessary is, after thorough scrubbing and drying, to cement the cut surface on to plate glass, and to cut off a slice of about one-sixteenth of an inch in thickness.

The second surface of the slice has now to be ground down on a glass plate with washed flour emery, until light will pass through.

Should the first section, however, not be flat, the process is very tedious. As emery splinters the edges even of imbedded crystals when rolling over the surface of a slab of rock in the process of grinding, it is necessary, in order to guard against this accident, to employ it in a state of extreme subdivision, and of perfect uniformity of grain. A much better article is to be obtained by repeatedly washing ordinary flour emery (separating the coarse, and setting apart the floating scum), than by using the "mirror flower" of the shops. The whole surface must be "brought up dead flat" (as in making a microscope slice), cemented by balsam on to plate glass, and the second surface ground down, if not from the very commencement with the fine emery, at least for such a length of time that all the pittings and roughnesses caused by the coarser emery are entirely smoothed out.

From the great consumption of time such sections are very costly; but by no other process are those crystal arrangements of rock structure which lie between the powers of recognition of the eye and of the microscope suitably and fairly disclosed.

Such slabs of rock are, when held between the eye and a bright light, found to be more beautiful, merely as transparencies, than jaspers, carnelians or moss-agates; while they at the same time often display the reign of law—dominating over the self-assertion and segregatory isolation of individual minerals.

The hornblende schist, when thus examined, presents a most singular appearance. The garnets which it contains are promiscuously scattered as regards crystal position, but may be said to be equidistant. The hornblende is in form like minute grains of rice. These grains sometimes, though rarely, infold the crystals of garnet in successive layers, so as to form a kind of sheath to each. Usually, however, they are grouped so that they project in clusters, their long diameters *standing erect from the angles of the garnets*, which are thus set round about with a series of plumose arrangements. Such granules as lie intermediate between garnet crystals, present the appearance of a current flowing between islands.

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The impression conveyed is that, after the solidification of the garnets, a specific force of crystalline attraction and polar arrangement emanated from them, which not merely influenced but *determined* the position of the crude crystals of the hornblende, notwithstanding the dissimilarity of the two minerals in composition, and their discordance in crystalline form.

Two other rocks spoken of above are deserving of notice here, from the fact that the nature of both may be said, on a first impression, to be rendered more obscure; while the interest of the first is exalted by the fact that the microscope altogether fails in directly determining its nature. The one is the pale green or yellow schist occurring in thin layers; the other the hornblendic rock which overlies the former a little higher in the series, among the flags at the foot of Sgor-a Chonais-aite.

Sections of the yellow schist, cut transverse to the bedding, show a zoned structure which is for the most part made up of more or less continuous layers of quartz. These traverse a confused arrangement of imperfect crystals of a yellow mineral which is unaffected by the rotation of the polariser. Rude crystals of magnetite are sprinkled here and there, with blotches of a dull-white substance which is probably an altered felspar. Both the upper and lower surfaces—those, namely, which had been the contact surfaces of the bed,—contain flakes of hornblende. A parallel slice, cut medial to the bed, shows no hornblende, but exhibits strains; these pass through the yellow crystals as a line of deeper tint, and through successive portions of the quartz as zones of fluid cavities. The quartz-granules are united by a sutured structure. Rarely, minute well-formed crystals of the yellow mineral, which are apparently oblique, are imbedded in the quartz.

With the upper Nicol the yellow-green mineral gives a play of colours so much more brilliant than is to be expected from epidote, that the determination with the microscope cannot be said to be absolute or satisfactory, the information afforded being negative.

By comparing the slices, however, with the *epidotfels* from Amerbuch in the Odenwald, Hessen, an almost perfect identity of appearance is seen. The rock from Hessen has fibrous hornblende filling rifts, a little augite, and garnet instead of magnetite. The crystals of epidote, also, are larger, and the structure is not altogether so schistose. No other differences can be seen; so this may, with some measure of confidence, be set down as *an epidotic schist*.

The hornblendic rock has, in hand specimens, much of the appearance of a dark mica slate, with the mica scales running out along one axis after the manner of Haughtonite.

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When sliced parallel to the bedding it has a harlequin-coat appearance; a uniformly disposed mélange of hornblendic structure, less felspar, and magnetite. The last is in quantity about one-third of either of the others; these occur in nearly equal amount. The hornblende is pale sea-green, and in rice-grain crystals, with feeble lineation. Revolution of the polariser produces hardly any effect.

A transverse slice, again, shows a zebra-like arrangement of the hornblende, which in this position shows normally dichroic.

This is thus a gneissic syenite, with a marked polarity in the arrangement of at least the hornblende. So dominant, indeed, is this polarity, that while the transverse slice, viewed as a transparency, is brown in colour, the parallel slice is pale blue-green; and in neither of the slices which I have have I seen a single crystal so placed as to show the lozenge cleavage.

The hornblende crystals thus lie with their long axes parallel to the bedding of the rock. The other direction—evidently equally definite—I unfortunately, not suspecting any such arrangement, failed on the spot to note.

The Granitic Rocks in the East of Sutherland.

As the continuation of the section through Sutherland from Ben Hope to the Helmsdale district would, from the almost total absence of shelter eastward of Ben Klibreck, entail great hardship, the writer preferred to undertake a traverse further to the north; and that so near to the boundary of the county that any obscurity in inland districts might be removed by a detour to the shore exposure. Such a section is easily made by starting from Whitten Head, and availing oneself of all the conveniences associated with the line of road which stretches eastward across the country to Thurso.

I have, in the rude sketch of the Whitten Head (Plate xxxiv., Vol. iv.), shown the stepped fault, with the appearance of local western thrust of the eastern gneiss which is there seen. At the time of examining it I was of opinion that, if the fault there disclosed could be shown to extend in force southward, Nicol's contention as regards the structure of this part of the country might, with some slight modification, prove to be correct.

I accordingly, in company with Mr. Dudgeon, spent some time at Hope Lodge, in examining the surrounding ground, which we traversed to considerable distances all round. We endeavoured to keep the line, and trace the fault southward from the Bodach Derag in the direction of Hope Lodge. The latter, however, we failed to do for any great distance, partly from the obscurity of the ground, but chiefly from all marks of disturbance ceasing. We were satisfied that the fault died out before

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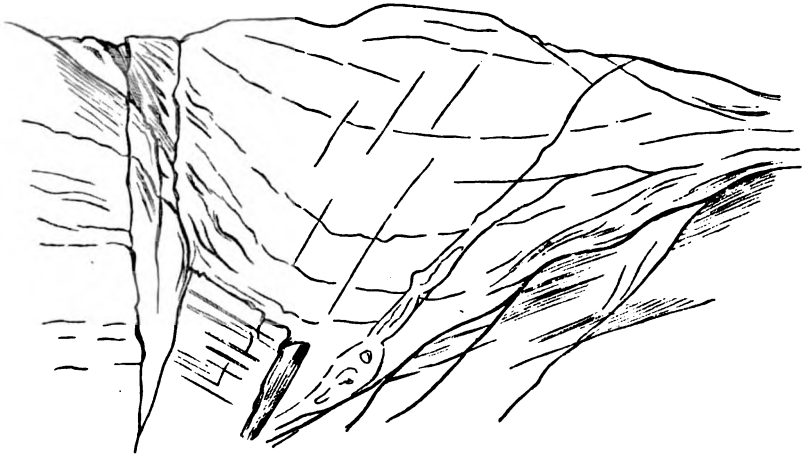
Cnoc an-Uillt Tharsuinn was reached. Close examination of the fault itself satisfied us that there had been no over-slide of the gneiss. As will be noticed in the sketch, the fragments of quartzite are all pulled or have fallen downwards; while some at the bottom have a tilt to the east. There is also a total absence of all rolling up of the truncated end of the beds of the quartzite.



A second sketch of the fault, drawn at right angles to the first, is now given. The exposure here is along the strike. The sea has cut away the quartzite, forming a little bay; and it has, to a small extent, impinged upon the gneiss, laying bare its shorn-down face. The lines of bedding are full disclosed, and the manner in which the beds droop to the centre, with dislocated fragments of the quartzite pitching against them to the downthrow, is suggestive of anything but an over-slide.

Again, an examination of the ground in the vicinity of the Lodge led to the conclusion that the beds on the west side of Loch Hope and of the Hope River ascended by an unbroken sequence into the upper schists. No palpable break is to be seen either in the shore cliffs, or is in any way indicated in any traverse of the Moin, or even in the appearance of the hills which skirt it to the north or to the south.

These upper schists, where they first come in, are in a general sense micaceous for a long way to the south; indeed until Loch More is approached. There is, however, considerable variation in their structure, and probably also in the composition of the mica. In the north, this ingredient is dark green, plicated, and greasy in lustre; in the south, it is purplish-brown, flat foliated, and splendent. I have indeed very considerable doubt as to its nature in the northern rock, which was called

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"chloritic schist" by Murchison. I have made repeated but unsuccessful attempts to separate from the rock a quantity sufficient for analysis. It may be an intimate mixture of margarodite with a decomposition product of hornblende.

Underlying the mica-slate of Ben Hope, there are, on the west side of Loch Hope, beds of a loose-grained quartz rock, with high sparkling lustre; and something of the same kind is seen in the beds of Leiter-Mussel; besides this, none of the rocks on this horizon exhibit any of the appearances which to the unaided eye are considered typical of high metamorphic action.

As the Kyle of Tongue is approached, what little can be seen of the rocks shows them to be gneissic in structure; felspar being abundant, but mica deficient. At the Kyle, a rock which has been called mica-slate is seen on both of its shores. For the most part it is a laminated quartz rock,—a mica-slate without the mica,—hard, tough, flinty, durable,—clearly highly metamorphosed.

Eastward of this,—and eastward, be it noted, of the line of overlying outliers of the Old Red Conglomerate,—there is a long stretch of country (as far as Strathy) where the rock has much the same type,—that of a "gnarled gneiss."

The usual, and stratigraphically the prevailing, dip, is to the south-east; but there are numerous folds. These are altogether trifling in amplitude; but in the centre portions of the tract they suffice to crumple up the rocks into a surface of extreme ruggedness. The gradual appearance of hornblende, and the separation of the several constituents of the rock into segregatory veins, has also here conferred upon it appearances of much increased metamorphism.

In the immediate neighbourhood of Strathy, and on at least the east shores* of the promontory of that name, a pale tint has returned to the rocks, either from an actual increase in the relative amount of quartz and felspar, or from the hornblende being here in segregatory belts. Albite also is now largely present.

Eastward of this point, and on to Reay, the rock may be said to be again distinctive.

If the hornblende has not actually increased in quantity, it has, along with black mica, been diffused so much more uniformly throughout the rock that the tint is for the most part dark. The rock is minutely lineated, but the lineation is not segregatory; for each layer which developes the lineation contains (though in varying amounts) all of the

*I have not examined the west shore.

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constituents of the rock. These occur in minute crystals, and have a granular arrangement.

The rock in fact is a granitic—or, more correctly a *syenitic* gneiss.

Occasionally, as near the Jibigall burn, it is even porphyritic, containing large crystals of orthoclase.

As we pass still further eastward, the granitic change increases, so that everywhere here,—and I believe everywhere to the south where it approaches or comes in actual contact with the present margin of the Old Red,—it has either actually passed into syenite or granite, or is a rock in which the gneissic structure and the gneissic bedding are more or less obscure.

In a map by Murchison, in addition to the large masses of granite laid down in the border-land, there are to be seen numerous sprinklings of small patches which are laid down all about the Strathy and Farr districts. These probably are to be held as representing small eruptive intrusions, seeing that the larger masses are held to be such. Not being able to discover any such masses at the point indicated, the writer concluded that they might represent a more condensed development of exfiltration granitic-veins; and the general appearance of the rock in the district between Strathy and Farr led to the expectation that such would be found.

This is exactly, however, what does not occur. With the exception of the east coast of Strathy Point, afterwards to be spoken of, the rock is one of fairly uniform structure; and what venation does occur is a *segregatory arrangement*, and not one of *granitic exudation*. The change in the nature of the rock is in fact one which comes in gradually, and which *occurs in masses;* while the evidence of the facts seen is *everywhere* against the view that these masses are eruptive. All the clearly exposed localities evidence that they are metamorphic.

The most westerly point at which the granitic rock is seen, is the shore line between Baligal and Port Skerry; the next at the Red Point, just within the confines of Caithness; the third in the neighbourhood of Sandside, specially at the Isald Burn,—whence it stretches as a more or less perfectly transmuted rock southward for many miles, passing under the Old Red rocks at every spot where the junction can be seen.

These are the three localities at which the question, *eruptive or metamorphic ?* has to be put to the rock itself and to its surroundings.

As this question has been directly entered upon by Sedgwick and

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Murchison,* by Cunningham,† and indirectly by Geikie,‡ the evidence and opinion of these authorities must be considered.

Of the rock in the neighbourhood of Port Skerra, Sedgwick and Murchison (1835) write:—"Two masses of granite interrupt the regular range of the sandstone strata, which are in consequence tilted in opposite directions from these granitic nuclei."

Of that at the Red Point they write:—"A mass of granite, in rude prismatic forms, here intrudes upon the stratified rocks. On the western side of this junction the beds are in the utmost confusion, the limestone being not only highly inclined, but also crystalline and cellular. Close to the point of contact these same beds assume a brecciated structure, and even contain many fragments of the granite itself. It appeared to us that the disturbed and brecciated masses could not be brought into comparison with the old conglomerate of Port Skerry, but had been formed by the mechanical action of the granite, which must in that case have been protruded in this place, after the deposition of the part of the secondary system above described.

"Some masses of the conglomerate rest upon the tilted edges of the limestone, whilst others are of a wedge shape, and appear as if they had been mechanically driven in among the shattered edges of the higher beds of limestone and sandstone. The cement of the conglomerate is generally granitic; it is, however, in some parts calcareous, and in other places it approaches to the character of sandstone:—one great block of sandstone, with the usual undulating surface, seemed to be entangled in the granite. At the eastern extremity of this disturbed portion of the cliff there is no conglomerate, and the stratified beds cannot be traced into immediate contact with the intruding granite; neither do their dip and direction appear to have been much disturbed.

"This mass of well-characterised granite may be considered as the extreme spur of a ridge of that rock, which, in retiring from the coast, is first seen in rounded knolls on the north of Sandside House, whence it ranges to the south-east, and rises into a low chain called the Dorrery Hills, which are peninsulated amidst the plains of calcareous schist and sandstone of Caithness."

Again, Murchison,* writing in 1859, says:—"In travelling eastward (from Farr) intruding bosses of granite again prevail; and some of these not only penetrate the crystalline strata but also throw off the overlapping Old Red Sandstone and Caithness Flags." "The bosses of granite on the shore near Port Skerry have evidently penetrated, when in a molten state, into the gneiss; whilst both these rocks have afforded the fragments composing the lower breccia and conglomerate. In truth, all this part of the coast having been subjected to violent breaks and faults, the hard crystalline granite, porphyry, altered rocks and gneiss, have in such movements been necessarily protruded here and there through the softer sandstone and flagstone. But that all such crystalline rocks were previously solidified is proved by the fact that their materials forming the breccia and conglomerate here constitute the highly irregular base of the Old Red Sandstone. In proof of the very local character of the coarse breccia, the observer has only to move to Reay, and in the banks of the burn of Isauld to the sea shore he will find that there the fundamental granite has undergone no dislocation; and that the conglomerate, or base of the Old Red lying on it, consists of pebbles which have evidently been rounded by the long-continued action of waves upon a shore."

In criticism of the observations of Sedgwick and Murchison on the appearances at the Red Point, Cunninghame, in 1839, writes† :—"Messrs. Sedgwick and Murchison appear to be of opinion that the secondary strata have been acted on by the granite.

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* *Trans. Geol. Soc.* 2nd Ser. Vol. III.

† *Trans. High. Soc.* Vol. VII.

‡ *Trans. Roy. Soc. Edin.*, Vol. XXVIII.

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* *Quar. Jour. Geol. Soc.* Vol. XV.

† *Trans. High. Soc.* Vol. VII.

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I saw not one appearance which could justify this belief. The circumstances appeared to me to present only a well-marked instance of strata reposing on a rock, which had in nothing influenced their position after they had been deposited." "We have here an example of a rock which, besides being partly derived from the subjacent one, has been also quietly deposited in its hollows, and on the edges and planes of the strata."

Speaking of the same spot, Geikie* writes:—"Three quarters of a mile westward of Sandside Geo, a portion of the uneven platform of crystalline rocks rises up through the later deposits. Bosses of gnarled gneiss and dark mica-schist, traversed with pink granite veins and with an easterly dip at high angles, appear on the shore reefs, and rise up to the summit of the cliff. The singularly unequal surface presented by these ancient rocks when the Old Red Sandstone began to be laid down on them is well shown by this part of the coast. A pink granitic breccia with intercalated seams of green sandstone and flagstone occurs at the base of the overlying strata, filling up hollows of the gneiss and allowing projecting parts of that rock to be wrapped round by the succeeding sandstones. This breccia is so hard and crystalline as to be in part scarcely distinguishable from a jointed granite. Some calcareous bands are here, as usual, associated with the base of the flagstones. A few small faults have the effect of here and there bringing the sandstones and the gneiss together along a vertical junction line."

It has first to be observed, with regard to these quotations, that as regards the two westerly localities the rock termed granite by Sedgwick and Murchison is regarded as gneiss by the other observers; while their writings show that there was a perfect agreement among all as to the nature of the rock at the Isauld Burn,—the easterly locality.

Again, Murchison and Sedgwick contend that the granite at Port Skerry was eruptive *in situ*, and that it was connected with eruptive movement—was indeed possessed of inherent "mechanical action" at the Red Point.

I would say with regard to these two localities that, as the rock at both is separated by a cincture of flags and sandstones from the gneiss of the interior, we cannot at either trace *progressive* metamorphic change up to and into it; and that the difference in the name applied to the rock by the above authorities shows that it may be regarded as being intermediate in character. This, indeed, it appeared to me to be.

The fact of granite *bursting through gneiss* at Port Skerry is not noticed by either Cunningham or Geikie; neither could I find any spot at the locality which presented such an appearance. The rock appeared to me to be pretty uniform,—a red granite rock, with little quartz and less mica, but still one which evidenced a gneissic origin. But the coast line, where it is exposed, is so extensively cut up by sinuous and branching "geos,"† and the foothold along the verge is so precarious from slippery grass,—which mantles a steep deposit of "till" down to a crumbling edge overhanging rocky spikes rising from a seething ocean,—that it is very possible that

* *Trans. Roy. Soc. Edin.*, Vol. XXXIII.

† "Geo" is a local word in the Northern Counties for a small creek or rent in a rocky coast.

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I overlooked the spot referred to. Again, neither Cunningham nor Geikie seem to have observed "the sandstone strata tilted in opposite directions;" nor could I myself find any spot where there was any such departure from the usual dip.

As to the second locality—the Red Point—Cunningham and Geikie are perfectly in accord, (except as regards the term by which they designate the rock). With these writers I entirely agree. I cannot conceive how beds of sandstone and limestone, brecciated by the upward thrust of previously solidified granite, and mingled with fragments of the same, could have a cement which, generally granitic, was still in some parts calcareous and in others of the nature of sandstone: and if, as Murchison puts it, "all the crystalline rocks were previously solidified,"—*i.e.* previously to their having been subjected to violent breaks and faults,—how could a great block of sandstone "be entangled *in the granite itself*"?

Murchison considers that the granite at the Red Point is connected with the knolls on the north side of Sandside House. This inference I conceive is quite borne out by the configuration of the ground. That the knolls north of Sandside are connected with the cluster, equally near, to the south of the road is perfectly evident. And that these are connected with the gneiss of the watershed about Loch Holliston on the west, and with the syenite of Isauld on the east, I think will be admitted by every one who examines the ground.

In passing eastward from the western watershed of the syenitic gneiss, it is seen that its bedding, its dip, and the lineation which vouches for its original laminated structure, are gradually lost. The rock which pierces the turf at Achavarsdal Lodge some would term syenite; others, granitic gneiss. A hand-specimen broken from any part of the rock is nothing but syenite. Standing some feet away, faint traces of paler felspathic banding disclose the prevailing dip and strike of the gneiss (as seen some miles to the west). Looking from this point southward to Creag Leathan, the bedding and the dip of the rock are clearly seen. Standing on the Creag, neither are to be made out; and one does not know what to call the rock, except *an intermediate*. Walking from Creag Leathan to Beinn nan Bad Mhor, and back over Beinn Ratha to Beinn Ruadh and the gneissic watershed, most of the ground laid down in the maps as granitic is passed over; and while many varieties of intermediate rock are seen, it is, as a whole, more clearly bedded and more clearly gneissic in structure than is the rock which forms the passage-beds in a direct line.

There being no encircling band of sandstones cutting off this syenite of Isauld from the gneiss,—as in the case of the two previously considered

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localities,—the question as to metamorphic transition should here be decided.

At the mouth of the Burn of Isauld the rock is altogether uniform in structure, in all respects and directions. Neither bedding nor any definiteness of arrangement of the component crystals can be seen. As noticed by Geikie, there is a large proportion of black mica; but there is a still larger proportion of black hornblende, while brown *sphene* is far from rare.

If it be a metamorphic rock, the metamorphism is here complete. There is not the smallest tilting of the overlying beds of the Old Red. The first bed indeed is a conglomerate, made up of smoothly rolled nodules of the syenite; and this bed passes under the flaggy beds with a dip identical with their own. Further inland, where some trace of bedding is seen in the syenite, it passes with an angle of about 15° under the same flaggy rock, which has a dip of about 8°. There is an overlap of each bed of an ascending series of the flags, mantling up upon each little knoll of the crystalline rock, which formed a shore-line to each succeeding bed, supplying to it a fringe of conglomeratic shingle. This conglomerate varies in character from well rounded *syenitic*, to nodular *granitic*, and angular *gneissic*, according to the nature of the local base.

It has been objected to the rendering advanced by Messrs. Murchison and Geikie of the sequence of the rocks of the north-west,—and the objection has been repeatedly brought forward, as if it were the sure ground of an unanswerable logic,—that it is exceedingly repulsive to geological science, if not opposed to all *à priori* reasoning, that a series of highly metamorphosed schists are made to overlie quartzites and limestones, which are feebly metamorphosed, if at all;—and, secondly, that the metamorphism of these upper schists themselves increases as we pass eastward, that is, ascend on the series.

This objection has sometimes been enforced in terms which seem to imply that the objector conceived that the very enunciating of such a view was the conveying of a slight to the intelligence of those who were asked to consider it. The first part of this objection falls to be considered afterwards; as to the second,—the impossibility, or improbability or irrationality of supposing it possible that the *upper members* of a series of rocks should be in the most advanced state of change,—it has simply to be replied, as regards the series of rocks which lie between Loch Hope and the Isauld burn in Caithness, that *it is the fact*. The lowest rocks have been declared to show little evidence of change; the highest is a syenite, as uniform in structure and as brilliantly crystalline in aspect as anywhere occurs.

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Present circumstances hardly suffice to show how this has come to be the case. We may inquire whether past circumstances can throw any light. To do this we will retrace our steps as far as the east shore of the Kyle of Tongue. We are there on the western fringe of the tract which in its gnarled and hornblendic gneiss, wrinkled into a rough and abruptly undulating country, had assumed distinct features of the operation of alterative processes; and we are at the same time looking upon an extensive line of Conglomerate outliers, which vouch for all the low country east of them having had to sustain the burden in heat and pressure of a new formation drawn over it like a blanket.

These outliers are proximate to the western fringe of the blanket. There is here but little evidence of the blanket having been continuous along the north; there being there only one outlier, it may have been tattered at the edges and thin in the fringe. But when we pass to about Bighouse, where the rock commences to be syenitic, we have come to a part of the country where the gneiss is, along its northern shore-fringe, overlaid nearly continuously by the flags of the Old Red Sandstone.

Hugh Miller described Sutherland as a gneissic picture set in a frame of Old Red; and this shore-fringe is the north side of his frame.

But Hugh Miller seems not to have observed that the workman had left fragments of his frame sticking every here and there over the surface of his picture. Such fragments occur at Drum Holliston, to the east of Ben Ruadh, and south of Milton Moss;—deep holes in the floor of the old lake, out of which denudation has not scoured all the shingle and the silt laid down in them in Old Red times.

Had he drawn any inference from these *valley-outliers*, taken in conjunction with the *hill-outliers*,—the Griams and the range at Tongue,—and had he considered the nature of the materials of which each consists, he must have seen that the Old Red formed no mere frame;—that the outliers represent but the fragments of a formation which had once been continuous, and which had mantled at least all the lower portions of the intermediate land.

It was my fortune, along with Mr. Tait of Thurso, to light upon another outlier; and one which vouches in a striking manner for the thickness of the formation at that part of the country.

Upon the south-east side of Reinn Ratha, in the bend of the hill between its two highest summits, and at a height of 775 feet, we found several beds of white sandstone, circling round the hollow for a considerable distance. This sandstone is very similar to that seen at Isauld, Bighouse and elsewhere. I have not heard of such a rock occurring elsewhere in

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Caithness, at anything like this height. A somewhat similar bed, but distinctly more argillaceous, occurs in the Dorrery Hills, at a height of about 650 feet; but as that bed dips to the north-north-west at an angle of about 4°, and as these hills are eight miles to the south-east, it must underlie the Beinn Ratha beds at a great depth.*

This section, then, goes to prove that *the syenite of the Reay district* is metamorphic, and not igneous; and that it was formed by a secondary metamorphorism of the hornblendic gneiss. This section also demonstrates the fact that the former circumstances in which the higher beds of the upper gneiss were placed were that they had been overlaid by a vast thickness of another formation; circumstances which supply pressure and heat, which are usually regarded as chief factors in metamorphic change.

Speaking of the basement beds of the overlying Old Red, Geikie writes:—"As on the southern margin of the Highlands, so here, the crystalline or metamorphic character of the older rocks was as distinct as now before the formation of the conglomerates. The metamorphism of the gneiss, quartz-rock, and other associated bands, and the extravasation of the multitudes of granite and quartzite-porphyry veins, had been completed long before any portion of the Caithness Old Red Sandstone began to be laid down."

Clearly the "metamorphic character" of the older rocks had been perfect, and the metamorphic change into gneiss and quartz rock had been completed *as such;* but many authorities hold that gneiss may undergo *a secondary metamorphism*, and be transmuted into granite and syenite. If so, all metamorphic change is not *completed* by the time that the rock has become gneiss. A secondary metamorphism may be yet before it; and it is this secondary metamorphism which is being now considered.

We are, in this consideration, at the very outset brought in face of an apparent difficulty. If the rock had not been metamorphosed into syenite *before it was overlaid by the strata of the Old Red*, how could conglomerate beds of syenitic-shingle have been formed? A ready answer is, the change *in both* may have been effected afterwards; as the agency which could alter the large mass would assuredly suffice to effect the same change upon the fragments. But, it may be replied,—not without cementation and reunion of the particles. A certain amount of this may be admitted; but a new or increased crystalline arrangement of the particles of a loose

*These Beinn Ratha beds, which are hanging on to the side of the hill like a fringe, prove that there was *here* no passage of ice from the E., S.E., or S.

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fragment could hardly, in the circumstances of the case, go the length of a new crystalline protrusion from the surfaces of each fragment, so as to produce mutual interlocking, and the formation of a uniformly solid rock. Some such process,—some such protrusive interlocking,—or some such infolding on the part of the more tractable felspar, does, under greater pressures and at greater depths, result in the formation of crystalline grits, and effect the all-round re-agglutination seen in clastic rocks. Moreover, if Macculloch and Cunningham and Geikie's accounts of the basement conglomerates of the Burn of Ousdale and of the flanks of the Scarabins, —the deep depths of this formation—be read, it will be seen how great an amount of this reunion *has* been effected. All agree that it is not always possible to determine where the solid rock ends, and the once-fragmented rock begins. Geikie speaks of a felspathic sandstone near Badbea "which is so distinctly cleavable that it might readily be mistaken for a porphyry vein." Here the granulated felspar must not only have been re-agglutinated but recrystallised; and that as perfectly as the calcite in Fontainbleau sandstone. The question comes to be very much this,—Would or would not the amount of pressure and of heat, &c. which enabled the dislocated particles of a crushed rock to reassume the structure of an uncrushed rock and present a definite crystalline arrangement, suffice to enable previously crystallised particles to assume a new crystalline arrangement?

There is an observation which can be made while examining the syenitic conglomerate of Isauld, which bears upon the question. It is this; on account of a thin investing layer of mud (the condensed slime from the foam of waves), the nodules of this conglomerate have so feeble a grip of the matrix that they may be easily knocked out. If the layer of dirt be removed by a hard scrubbing brush, it will be seen that the hornblendic crystals which meet the surface are cut across, and the nodules, as a whole, are polished; and the lens discloses that it is a surface of *truncated crystals* which is polished.

But yet again has the other side to be stated;—sections of the nodule, and of the reagglutinated cement or paste show that the crystalline structure *is as intimate and as coherent* in the one as in the other; and the lines of fracture cannot in the latter be discerned.*

* All that has been written above as to the mode of formation of the syenite of Reay is submitted by the writer as nothing more than a *consideration of the subject*, —a suggestion of a possible mode of formation. He is not to be considered as "maintaining it," or "believing it," or anything of the kind. The dogmatism of many geologic writers,—the dogmatism of all scientific theorists,—is to him an

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Whether the presence of the overlying Old Red in any measure has brought about the secondary metamorphism or not, the facts remain that metamorphism may be traced in successive steps up to the present fringe of the newer rocks;—and that granitic and syenitic rocks occur along most if not every part of that fringe, for some distance back, that is, west thereof,—while it will be seen they are also exposed through denudation several miles to the east also.

If the syenites and granites of the Reay patch can be connected with the great mass of the same rock in the district of the Knockfin heights, and if that can be connected with the Ord, Loth, and Culgower mass, it is safe to argue that these also are metamorphic. Such connection might be traced, if denudation has at any intermediate spots exposed the lower rock to such an extent that it could be directly seen whether it was metamorphosed. It might also to a certain extent be indirectly traced if a local base of the series was exposed, and that was found to consist of a granitic conglomerate.

Geikie writes: *—"From Reay south-eastwards the granite and gneiss are fringed with sandy and pebbly strata, not, however, as a continuous mantle sloping away from them, but in successive beds, abutting against the eastern edge of the crystalline area, and dipping towards the north-north-west, or north-east."

This I read as impressing the fact of the overlap of the flaggy beds upon the crystalline strata; and not as intended to convey the meaning that the pebbly fringe is confined to the horizon which at the present stage of degradation happens to be the visible junction of the rocks.

Certainly if the dip of the overlying flags had been away from the crystalline rocks, the drag of its fragmented portions would have carried them further away from the shore-line where they were produced, and so have formed a more continuous mantle; and equally certainly must we expect to find that all elevated points of the very uneven bottom-rock will, if granitic, be surrounded and mantled with a granitic conglomerate.

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utter abomination. Did we, with regard to points which are *subjects for inference* and nothing more, less often read such expressions as "this is," and "this was," we might has been spared the following cruel lashing from one of the most earnest and most conscientious workers whom this country has known,—"I am not sure, not exactly sure, whether the deductions of scientific men are always such as to merit the approbation of Heaven. Of all geologic reasoning one soon gets tired. There is nothing on which the mind of the reader can lay hold, and rest. 'What is truth?' is an old question; but no man in his senses would seek for it in the books of geologists."

* Loc. cit.

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We may not get down to the fixed rock at many points, but we may reach here and there its immediate envelope of conglomerate. The inference, however, is not an altogether safe one, for although conglomerates are *usually* shore or shallow water deposits, and also usually, as Geikie puts it, "notoriously local formations," yet their component blocks have frequently been swept considerable distances from the parent rock. A conglomerate of markedly distinctive character we may safely conclude does not lie far removed from its source;—witness those of Isauld, Red Point, and Port Skerry, the last of which Sedgwick and Murchison declared "could not be brought into comparison" with each other; and yet they are distant only three miles, and are possibly on the same horizon.

Having traced the syenite and syenitic gneiss southward to within about three miles of the railway at Beinn nan Bad Beg, and observed a spur of the more westerly range of the same rock to approach it somewhat nearer, I found the country to the south so swaddled up in continuous boggy moor that nothing was to be learnt. Mr. Tait, however, informed me that a crumbling granite was dug into for gravel, near Alltnabreck station, and showed me a quantity; while in passing along the railway cutting I observed decomposing granite, but certainly *in situ*, on both sides of the line between Sletill Hill and Cnoc nan Gall.

It is thus clear that the granite of Reay is continuous with that great expanse of it which stretches along the Knocklin hills southward to the quartzite of Cnoc nan Eireannaich.

A traverse was next made across the Dorrery Hills down to Dale, as Murchison states that these hills are granite; but having observed flaggy schists lying between them and the syenite of Beinn nan Bad, I had some doubts of the accuracy of the observation.

I found no trace or indication of the near presence of the older rock. The two hills show outcrops all round; these consist of thick beds of sandstones of a somewhat flinty description, with feeble layers of shivery flags. The beds dip to the north-north-west at a very low angle. They lie upon the other beds like two piles of oval "bannocks;" and I could see from their summits no beds with which I could connect them. They are the remains of upper beds seen nowhere else in this part of the county.

Having been informed by Mr. John Gunn that igneous rocks appeared at Dirlot, in the bed of the Thurso River, this locality was visited and proved in many respects a most interesting one. It is an illustration in little of Niagara, only that here the river has finished its work, while at Niagara it has not.

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The river runs in a curve, and, in a general sense, from south-west to north-east. At the lower end of the curve a granitic rock, and at the upper, about a half-a-mile distant, a gneissic rock, have been faulted (?) up, bearing between them a shallow trough of some lower beds of the Old Red.

This triple structure, thrust aloft to a height of about 50 feet, had formed a dam to an old lake, a continuation of Loch More. This lake had been enclosed, and bottomed by water-dressed drift on all other sides than that of the rock dam.

Simultaneously the lake-waves urged by the south wind, and the river, mantling over the dam and running in a shallow channel, had engaged in sawing through the dam, operating from opposite sides.

From the south a sinuous off-set of the lake, and from the north a river-canon, were gradually formed, and unceasingly lengthened.

The stream clearly was working to greatest advantage, for it could always sweep away the gravel it formed, whilst the lake-waves often must have banked theirs up in front.

The river also, after cutting through the fissured and granular granite, had a much softer rock to operate upon than had the lake; hence, as will be seen, the river has accomplished about double the amount of work. At a certain stage of the double process, it had cut through the whole of the Old Red rocks, through even a basement conglomerate, before the lake had cut through the gneissic rock. Upon the remaining portion of this, both were now to operate.

The lake had been impeded, during part of its operations, by two unusually dense and hard belts of rock, the remnants of which thereafter stood in the lake as rocky islets; and it was ultimately and for long brought to a standstill in its work by the very last of the beds of gneiss.

This bed is tilted at a very high angle; it is laced through by veins of quartz; and it is backed by a thick post of a fine granular felsitic rock, which is possibly eruptive.

The lake could not attack this barrier, faced as it was by the wall of gneiss; but the stream, so soon as it had shovelled out of the trench the disintegrated conglomerate, attacked it; and this it did both by the mechanical force of its falling waters, and by sapping at it, in virtue of the solubility of the alkaline silicates of which the rock so largely consists.

The profound depth of the river at the foot of the truncated cliffs vouches for the protracted endurance of this barrier,—the removal of which left but the one belt of gneiss between the river and the lake.

An examination of the gneiss above, and a consideration of the rocky islets which now stand stranded in the turf, evidence the "gnarled" nature of this gneiss,—the inequality in thickness of its layers, and the variation in hardness and doubtless in solubility of its different parts. The islets vouch for and represent an original concretionary structure; and such a knotted concretionary structure is present in that one remaining belt which, it has been seen, had successfully resisted the sap of the waters of the lake. The concretionary portions of this belt were alone, however, destined to resist the friction of the running stream.

One of these bossy enlargements occupied the very centre of that part of this dam which faced the lake. Probably by the time that the stream had cut out the felspathic prop, the waters of the lake had curved round the harder part of the dam on either hand, so that that more enduring portion protruded southward at the centre, but was linked to both banks of the river by a dyke-like cincture.

Over these thin connecting bands the waters of the Thurso river were now falling in two cascades of equal altitude; ever deepening the gulf into which these waters fell; but also ever deepening the two notches in the dam, through which they were precipitating themselves.

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It was probably at this stage that the Castle of Dirlot was built upon what was now a rocky islet.

The Castle is figured and described as standing in a lake;—it certainly stood surrounded by water, and infinitely better protected than if it had stood merely in the occasionally still waters which surround a lake islet.

Waters in front of it, waters to right of it, waters to left of it,—behind it at a depth of forty feet a boiling gulf, and at either shoulder the ceaseless sweep and plunge of those waters which had cut a river canon near half-a-mile in length:—there is not a fortress like it in the world, nor will there be until one of the rocks of Schaffhausen, or Goat Island, are fortified! But the water finished its work;—on either hand it gradually cut away the dam down to the lake bottom; and since, has cut it on one side some feet lower.

There was some attempt to form a draw-bridge, but the stronghold is now in ruins.

This is not only a most interesting spot for studying the operations of certain physical agencies, but it is the most picturesque nook in Caithness.

The section at Dirlot, commencing where the rock rises out of the clay bottom of the drained lake, is as follows.

The first seen rock is a fissile red felspathic gneiss with a north and south strike (mag.), and a dip of 75° to east. This is highly metamorphosed, and has numerous thin quartz veins at right-angles to the strike. A little eastward it contains a 4-foot bed of fine-grained pinkish granite, which has little quartz. As we pass south, though still showing a gneissic lineation, it is almost a granite; the dip here is 60°. Near the bridge, and between that and the Castle, there is the delineation of some folding in the rock, which has still a gneissic appearance, but a granitic structure.

At the Castle the dip suddenly rises to 80°, and the rock is distinctly a gneiss, but is considerably metamorphosed.

Its last thick beds contain quartz-bands, with crystallised *ripidolite*, and rosettes of either *talc* or *margarodite*. There is then a thick bed of fine granular and very felspathic rock; but I could not satisfy myself that this was intrusive, and the cause of the tilting. This bed may be 50 ft. thick.

Rough, angular, tumultuous conglomerate, about 40 ft. thick, succeeds. While formed of fragments of the underlying rocks, it seemed to me to contain proportionally much more red-felspar granite than these rocks could have afforded. The nodules are imbedded in an exceedingly rough and nodular condition, and could not have rolled long on a sea-shore. This conglomerate appears as a whole to be more metamorphosed than are the underlying rocks.

Over the conglomerate there is a thin bed of micaceous limestone, above which are ochre-coloured flags, dipping east-north-east at 25° for about 160 yards. A shallow trough succeeds; the dip at both sides of the basin being only about 7°. There are traces of vegetables in these beds.

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Sixty yards below, still east of the trough, limestone is seen protruding out of the east bank of the river. The lowest visible portion of this mass, which is concretionary throughout, contains numerous imbedded fragments of granitic gneiss. Its upper portion is much rent; the rents being lined with crystallised calcite in the form *e. b.*

About 60 yards down the stream, granitic conglomerate occurs, best seen on the other side of the river; it has a very low dip to the west: then granitic gneiss with no evident bedding for 70 yards, when the same conglomerate again comes in with a reversed dip. A bed of micaceous limestone is now seen crossing the river diagonally, so that the dip is swinging round somewhat to the north of east. Over this there is a 15 ft. bed of flaggy grey limestone on the west side of the river, the dip of which apparently swings round still more to the north. This limestone is overlaid by boulder clay.

Red granitic gneiss passing into almost perfect granite has again come out from below the conglomerate on the east side of the river, and this continues down its eastern bank for some distance, when it in turn is covered by the boulder clay. It may thus be this granitic mass or spur which has swung round and thrown off the beds on the opposite side of the river.

The granite or granitic gneiss last noticed is so broken up, and altogether so unsatisfactory in appearance, that an opinion as to its nature can hardly be ventured on; its bedding is very indistinct, but it seemed to form an arch. Giving all due weight to the appearance of swing round in the newer rocks, I am still of opinion that at both ends of this section the rocks have been faulted up, though not to a great extent. The felsitic rock near the castle I admit may be igneous; still, if so, it has forced its way between the gneiss and the conglomerate without any clear marks of disturbance.

The manner in which the boulder clay at the south end of the section mantles up over the gneissic rock also prevents any decided opinion being offered as to a fault occurring there. However, as the rock is first seen on the opposite side of the river in much the same line, the existence of a fault is probable.

The whole mass has been by some writers termed granite, and it may be conceded that it is a fair example of gneiss having passed over into it; but there is nothing either in the appearance of the granitic rock, or of its surroundings, which connects it with the masses of the same rock in the west; it is here a mere local base. The occurrence and the appearance of this mass, with its beds dipping much in the same direction (though at increased angles) as do the beds of the same rock where last

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seen in the west, and its occurrence in the midst of the general flat of Caithness with no marks of disturbance anywhere around, strongly impressed me with the idea that a granitic or gneissic-floor stretched far into Caithness *at no great depth* below the flaggy rocks. Robert Dick evidently thought so; for, speaking of geological map makers, he writes, —"Oh bold men and daring! how gallantly have you set the truth aside! How inimitably you have run your Old Red in Caithness sheer up to the root of Morven, in defiance of every intervening obstacle. Outbursts of granite are nothing. Their iron-pointed crests (stubborn facts) standing up here and there are only trifles; yet they riddle in rotten holes your pretty pictures! Seriously, if any junction of the Old Red with the granitic rocks be as irregular and complicated as that in Caithness, it will be no easy task to delineate it correctly. It would require such an amount of time and patience, such a crossing and recrossing of the country, that few private individuals could venture on."*

It is to be remembered, moreover, that a granitic conglomerate has been observed far north on the east shore of Caithness; and this must be held as vouching for the near presence of granite.

The next portion of the country examined was the Morven, Braigh na h-Eaglaise, and Kildonan district.

The great pile of granitic conglomerate described as constituting the cone of Morven, leads to the expectation that there must be in the near neighbourhood at least the evidences of some pre-existent large mass of granite, throwing out perhaps a spur indicative of connection with Knockfin to the north-west.

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* But, if the dauntless Dick,—the man who could walk sixty miles a day, or rather a night,—who had his home in the country,—would not undertake it, there could not be much likelihood that one of those "gentleman geologists" for whom he entertained so great a contempt could accomplish it in a short visit. It is all very well for Dick tauntingly to excite to the work by writing "Try it, gentlemen geologists! Try it! Away through the moors; and again through the moors," when of these moors he gives us the following as his experiences,—"In the name of all that is truly miserable nothing can be conceived more dreary than those wide stretching heaths: nor bird nor insect is there, even the hardy club-moss has acquired a yellow hue; all is lonely and melancholy. The whole breadth of the country lies before with mires and moors unutterable. To linger might be fatal should darkness overtake. 'On, on,' is the watchword! On and on through marsh and mire, ankle-deep, and deeper! Hop, step, and jump is holiday diversion compared to passing over these rude hummocks. One's frame trembles with the concussion. Try it on the hummocks! Try to pick your way by wading through the pools of water. Try to get round and between them. It is all the same. You sigh in hopeless agony. You get bemired to the knees, and long for a clear pool of water where you may have a satisfactory washing."

It might have been better service of Dick had he left some more precise jottings of his own observations on these outbursts of granite.

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Several days were spent by Mr. John Gunn and myself in examining the district. Fired rock of a granitic nature was found only at two spots.

We found the fissile beds of sandstone which have so red or chocolate-coloured a cement, dipping under the Maiden Pap from the north; and, observing these to overlie an unusually rough conglomerate, which is best exposed in the north bank of the Berriedale Water under Con-na-Craige, Mr. Gunn examined that bank, and the Con itself.

He found the conglomerate to consist of very large blocks, which he described as being not so much rounded and rotten-looking as what occurs at Dirlot; and he found the Cnoc to consist of granite, disposed, as is indeed evident from a distance, in huge slabs.

The other spot at which we found granite is nearly directly north of Morven; here it occurs in the bed and banks of the Morven Burn. It is here in a state of extreme disintegration, and might almost be dug as gravel. It showed, however, an anticline, falling nearly east and west (mag.); and the bedding of the rotting rock was frequently more clearly delineated by layers of quartz.

I conceive that the conglomerate of the river bank may be possibly near the position of the basement conglomerate described by Geikie; and I fancied, from its appearance from the summit of Morven, that Ben Alisky, which lies due north of Con-na-Craige, might be granite. If so, these two hills, with possibly Ben Glass Choire, may form some of the granitic pinnacles to which Dick refers as piercing the pretty pictures of those geologists who bring the Old Red flags right up to Morven.

Should there be, or have been, a great mass of granite in this direction, the vast accumulation of conglomerate which forms this clustre of picturesque little hills may be accounted for. I cannot account for it otherwise, except by the supposition that neither the basement conglomerate nor the great cake of a similar structure, which overlies the red flags, has been derived from closely adjacent rocks.

The granitic nodules of the upper conglomerate do not much resemble any granite I know in the north. It is not like the granite of Loth; but as I conceived that that granite might change its features as it extended north, I walked over Sal Voich towards the granitic hill Braigh na h-Eaglaise. As I approached it, however, I saw no spot where the solid rock was exposed, and an examination of rolled masses swept from its foot did not support the view that the huge heaps, now hemmed in by Scarabin, Sal Voich, and the Small Mountain, had been carried from the very extensive stretch of the rock which passes southward from Braigh na h-Englaise to form the great mass of the Ord.

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The bedded nature of the rock on Con-na-Craige points to a metamorphic origin; but whether this mass is, or is not, continuous with the orthoclastic and highly granitic rock described by Geikie as occurring a few miles removed,—namely, at the north-east shoulders of the Scarabins,—only detailed plotting can reveal. All that can be said at present is, that if it did not lie immediately to the north, there is little indication here of any such mass of granite as could have supplied the material of the great upper cake of conglomerate. This in Morven towers some 800 feet above the nearest and loftiest portion of those lower-rocks which must have formed the local shore line or lip of the basin in which the conglomerates were deposited.

A strong argument in favour of the almost total removal of the mass of granite which furnished the conglomerates of the little cluster of Caithness Alps, is *the markedly local character* of the conglomerates in this district. Geikie speaks emphatically on this point:—"We find them to indicate with considerable distinctness the character of the more ancient rock beneath them. Near the granite they are made up in great measure of granitic debris. Round the quartz rock they are largely composed of that material. The existence of the well-veined orthoclase-gneiss is indicated some distance before the underlying rock is actually seen, by the abundant fragments of beautifully fresh cleavable pink felspar in the conglomerates."

I shall have, in speaking of the conglomerates at some of the local shore lines in the north, to adduce further evidence of the same fact; but such evidence is not wanting even here.

The only two spots I could find where there was a visible junction between the conglomerates and the quartzite were—on the north slope of Sal Voich, and at the east foot of the Small Mountain. The conglomerate at the first consists of mica schist, granite, vein quartz, and quartzite, with a granitic paste. The rock in contact with the quartzite of the Small Mountain is a purple flaggy sandstone; this has angular fragments of quartzite, half the size of the head, imbedded in it in all positions, but lying chiefly on the tops of the slabs. While this evidence is not so strong as that of the former locality, seeing that quartzite is only one of several constituents, still as quartzite is not seen in the conglomerate of other districts, its presence here and absence in these vouches for no great amount of transfer of the other materials of this conglomerate.

That no granitic mass lay *at the immediate spot* where the clustre of conglomerate hills now stands, I think is evidenced by the arrangement of the quartzite of Scarabin and Kildonan.

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This quartz rock had always, from what I had heard of it, been to me a puzzle.

Murchison figures it as dipping to the west: Geikie, as dipping to the east, under Morven; while Dr. Joass informed me that the dip was vertical. It was at least *hoped* at one time that it might prove to be the quartzite of the west, metamorphosed and brought up by the granite of the Ord;—the eastern lip of a basin which underlay all the rocks of central Sutherland. Geikie, however, makes it part of a regularly ascending series:—"Towards the southern corner of Caithness, the underlying crystalline rock is chiefly a rather fine grained pink granite. Further north this gives way to flaggy micaceous gneiss, dark greywacke, and quartz rock, which in turn, dipping gently towards north-west, are overlaid by the thick but lenticular band of white quartz rock of the Scarabin Hills. Higher still in the series comes a remarkably beautiful gneiss. Other bands of white quartz rock and dark schist occur further to the north." This leaves no question of its being but one of a series of beds, but it makes the dip *north-west*.

I found the quartzite to be disposed in two parallel ridges of hills. The southern and somewhat loftier range commences near the shore line and is nearly continuous to Sal Voich; west of this there is a considerable heath-covered depression, but it again appears in Creag Scalabsdale, and stretches through Creag nan Gearr and Cnoc Salislade on to Ben Duan.

The northern ridge comes out from under the western foot of Morven, and rises into the Small Mountain, whence it continues through Cnoc an Eireannaich (the Irishman) on to the westward.

Having walked along nearly the whole stretch of both of these ridges, I have to say that I am far from surprised at the discrepancy of statement with regard to the dip of the rock. There is much concealment from a sprinkling of loose fragments, and where the rock is fairly exposed, there is a jointed structure which dominates over the traces of bedding which the high metamorphism has alone left. This jointing in many places simulates bedding so perfectly as to engender doubt.

The rock is evidently highly metamorphosed; and is in many spots a breccia, in which the cement has united itself most intimately to the fragments which it agglutinates.

On the north-west foot of east Scarabin, and just above a rising ground called Shian, there are, at the height of 1000 feet, several beds of fragmentary quartzite. The fragments of this are cemented by a granular paste which is quite as much "vitrified" as are the fragments themselves.

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The colour of this cement, however, is deep flesh-red, while the fragments are pure white. These beds dip south-east at an angle of 6°.

So very fragmentary is the appearance of the rock, that it was only the perfect union of the parts, and the finding of overlying purplish clay-grits of the sandstone dipping to the north-west, that satisfied me that this was not a breccia of the upper rock. I afterwards found that this brecciated structure was characteristic of this quartzite, though it is generally seen in what are apparently its lower beds.

In the col between the middle and west Scarabin, there are beds 8 feet in thickness, which dip at an angle of 76° to north by west. The rock is still very fragmentary. On the north side of west Scarabin, massive beds are seen with a very slight dip to the west; while at the foot of a low shoulder of the same hill, the dip is to the north-north-west at varying but generally low angles.

On the summit of Sal Voich (1822 feet) the dip is north-north-west at 42°; while at the height of 1270 feet on its north-east face, the dip is only 7°.

On the south-east slope of the Small Mountain (1585 feet) at a height of nearly 1500 feet, the dip is to east of south, at an angle of about 85°. The quartzite here is much more uniform in structure, more milk-white on the surface, and more saccharine when broken, than it is at any point before noticed. The strike-joints show a series of striæ, as if there had been motion. There can here be no question as to the dip, as the bedding is distinct.

These observations go in the main to show that the quartzite forms a trough of which the parallel ridges of hills are the lips; this trough has high dips at the outer edges, and lower towards the centre of the hollow. The conflict as to direction of dip is possibly to be explained by supposing that Murchison's observations were made on the Scarabins, while we know that Geikie's section is drawn through the eastern end of the northern ridge.

The bed of the burn, south of "The Irishman," consists of flaggy quartzite, with mica clearly visible. The rock near the Kildonan burn also shows layers of deposit; so the rock at its western limits probably passes into fissile gneiss.

The question has now to be asked,—What caused the exalted metamorphism,—a metamorphism at first sight apparently very much greater than that of the rock occurring in the west of the county to which the same name has been most unfortunately applied?

Let those who hold that the granite of the Ord is igneous find junctions.

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What has again to be recorded here is, that the beds which are high in the series exhibit the highest metamorphism. Geikie chronicles still higher members of a "quartz-rock" nature, all abundantly traversed by veins of granite and quartz porphyry, or with ribbons and kernels of orthoclase.

Minerals.

It was noticed above that the gneiss of the district near Strathy was more veined than is usual. Many of these veins are to be seen near the mouth of the Halladale River, and along the east shore of the promontory. The veins themselves present a structure which is not usual. In one part pale blue vitreous quartz, in another a fine grained crystalline *mélange* of pink orthoclase with some quartz, and in another hornblende in laminated rice-grained crystals have segregated apart in bands of three or four inches in thickness. Those of orthoclase and of hornblende are geniculated, and appear to intersect the general mass, as veins within a vein.

When examined in section with the microscope the hornblende is found to be mixed with crystals of a milky-white striated felspar, probably albite. It is dark green, and highly lustrous in mass; but the section shows only pea green and blue green of pale tints, and is very feebly dichroic. Very seldom in a section which has been cut parallel to the sides of the vein are the crystals found to be sectioned transverse to their length,—the position of greatest dichroism.

It is thus seen that the long axes of the crystals lie *parallel to the sides* of the vein:—a fact which, taken along with their other features, shows that these, if originally veins of exudation of the material of the rock, have suffered a new arrangement of their constituents.

The gneiss here is highly *albitic*. Considerable masses of interpenetrating crystals, the sections of some indviduals of which show a striated surface of about two square inches, are occasionally found. Crystals of considerable size of form *m p x y t l n* occur. These are repeatedly twinned on the face *m*, and there is this peculiar feature to be observed in some of these twins—the relative thickness of the plates of the repeated twinning diminishes progressively from right to left of the twin, that is from *n* towards *e* (wanting), until it is so excessively minute, that the striation is only to be perceived by the microscope.

The general tenuity of the twin plates, and the pure white colour, are features of this albite.

Masses of it contain patches of a red granular felspar,—imbedded rosettes

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of *margarodite* (simulating talc),—massive crystalline *chlorite* pure in substance,—massive *pyrite*,—and *Haughtonite* of a deep brown colour.

The massive quartz rarely contains small imbedded nodules of *apatite*. These are transparent, vitreous, and of an asparagus colour. This apatite is totally soluble in nitric acid, showing no trace of cryptolite.

The granitic gneiss which protrudes at "The Red Point" contains a tortuous but nearly vertical band of very singular appearance. At the spot, both from its position and relations, and from its macroscopic aspect, I set it down as without question igneous. The appearance of a slice in the microscope, however, leads me to think that there may have been a rent in the granite, which has been filled up with a kind of grit. Still there is an aspect of very considerable alteration, if not of actual secondary crystallisation. The angularity of the fragmented portions—consisting of a striated felspar, Biotite, and quartz—is softened off. What seem to be crystals of either apatite or some acicular mineral, lie in interstices of the fragments, which these crystals sometimes have pushed aside and sometimes have apparently penetrated.

The mica slate, noticed by Geikie as seen here, is to me an unknown rock. As it contains no quartz, or almost none, it should not be termed mica-slate. A section shows a parallel arrangement of plates of rich brown mica, apparently *Biotite*, among which there are occasional rice-grain white crystals, seemingly a felspar.

The syenite of Reay has been mentioned as containing quartz, felspar, hornblende, mica, and sphene. The quartz, small in quantity, is vitreous; the felspar is white, bordered by red; the hornblende dark green; the mica, dark brown in colour, is apparently Biotite; the *sphenes* are hair-brown, and rarely well crystallised. The rock is one of very brilliant appearance.

It has been said that the rock of the neighbourhood is everywhere more or less syenitic. The perfected change generally appears in belts. One such—seen in the rock face on the north side of a great gash—which had probably been a former outlet of Loch Thormaid,—is singularly bordered by a belt of flesh-coloured felspar, fine in the crystal grain. This syenite contains well crystallised hair-brown *sphene*, in the forms *c n y* and *c n y r*.

Near Loch Scye, to the north of the first geniculated bend of the stream which flows out of it, there protrudes from a covering of heather a small boss of a very singular and, I imagine, *unique* rock. It is only some 25 yards in length and breadth, and about 10 feet in height. It has to a small extent decomposed into a brown granular soil, and this, from the lime and alkalies which it contains, has induced the growth of grass,

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so that the spot is visible from a distance on account of the contrast it affords to the brown of the surrounding heather. This boss is on all sides surrounded by syenitic gneiss.

The rock has a most singular aspect. It does not weather on the surface to the smallest extent, nor is it acted on by vegetable growth; so that portions from which the turf is newly peeled, and portions which have been exposed for some years, are alike as fresh in appearance as is a new fractured surface.

That surface spangles and flashes in the sun just as would a quantity of silver or bright steel buttons sprinkled thickly on a dark green sward.

Examined macroscopically, the silver buttons are seen to be plates of *talc;* the continuity of these being broken up by a knitted lineation which produces a surface-structure similar to that of shagreen.

The dark green material consists of foliated crystals of augite.

The talc crystals lie so close-packed throughout the rock in every position, that broken masses are found to have the fracture of their surfaces determined in almost all directions by the cleavage of the plates of this mineral. Certain points, however, show the interrupted fracture of the augite; which, from the tenuity of the plates of talc, must be present in larger proportion than outward appearance would suggest. The unaided eye discerns no other ingredient; but the lens discloses rare crystals of pyrite, and apparently a minute quantity of magnetite. The plates of talc are from one to two inches in magnitude.

When examined in the microscope, cut parallel to the foliation of the talc, it is found that this mineral is not everywhere transparent, but is for the most part brown and clouded, to opaque. Apparently the flour emery employed in the grinding has been forced between the folia of the talc. As the portions which remain transparent give a pearly reflection somewhat better than do those which are brown, there can be no question that the true appearance of the latter has been interfered with in the darkened parts.

The talc polarises with pale grey tints, and in cross section with brilliant tints which are disposed in an arrangement similar to that of a riband. The augite has occasionally a thin envelope of serpentine, which very rarely penetrates its rents. Ill-defined olivine is totally changed into obscurely fibrous serpentine. This shows no olivine rents, and is occasionally blotched with nearly opaque granules. Much magnetite is present everywhere. I could find neither felspar nor quartz.

The following statement of the composition of the rock was sent me by Mr. Hugh Mill, as the average of three analyses which had been con-

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ducted by him in the Laboratory of the University of Edinburgh. The analyses did not vary much as regards any ingredient, except the alkalies. These in one analysis were as high as 4·85 per cent. :—

Silica	42·10
Alumina	8·38
Ferric Oxide	8·27
Ferrous Oxide	2·18
Manganese Oxide	·70
Lime	8·77
Magnesia	30·65
Soda and Potash...	1·90
Water...	7·78
	100·53

The magnetite explains the ferric oxide; but as I could find no felspar I am unable to explain the presence of alkalies, and the water seems high for a mixture of such nature. To the eye the rock looks like a mixture, in equal amounts, of talc and augite. In its mode of occurrence it appears to be igneous.

Immediately to the north-east of Achavarasdal Lodge there is a very considerable deposit of iron ore; this has been previously referred to under the name of limonite. Having had an opportunity of thoroughly examining the locality and of analysing the ore, I find that it is *Göthite*, and that it occurs in the form of a bed, or more correctly of two beds.

Somewhere about 100 yards immediately to the west, the gneissic structure of the rock is faintly evidenced by a linear arrangement of the felspar; at the spot where the bed occurs it is a true syenite.

Three pits, at an extreme distance from one another of 800 yards, have been sunk upon the ore, to a trifling depth. So far as exposed, both rock and ore are in a state of complete smash. The rock is also considerably disintegrated, but not to such an extent as to account for the presence of so large a mass of iron as a mere result of the decay of the Biotite which the rock contains. Indeed, it cannot be said that the Biotite is altogether changed.

The strike of this bed of ore is north-east by north; which is very much that of the gneiss of the knolls lying in near proximity towards the south-west.

So far as the smashed condition of the ore entitles one to speak, it is not in the form of a vein. The dip of the sheet of ore, about 46°, is somewhat greater than that of the adjacent hill.

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The lower portion of the bed is in the form of massive ore with much disseminated quartz. Over this there is a layer of powdery red and yellow ochre, the latter possibly *xanthosiderite*. A thick band of ore follows,—cavities in which are lined with mamillations of radiated ore. Certain of these cavities are lined by acicular crystallisations in downy tufts. These have considerable beauty from their velvet-like surface, and rich orange-brown colour.

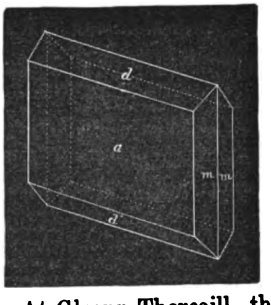
Pellucid *rock crystal* is beautifully capped and penetrated by feathery plumes of the Göthite.

An ochreous clay overlies the solid ore; and over this, with some feet of intervening rock, there is a thin vein of the same ore.

The analysis yielded—

Ferric Oxide	88·662	88·69
Alumina	·336	
Ferrous Oxide	·663	
Baryta	·11	
Lime		trace
Magnesia		·80
Sulphuric Acid	·06	
Soluble Silica	·67	·93
Insoluble Silica	1·112	1·88
Water	8·8	8·25
	100·353 (H.)	100·

The second analysis was handed to me as having been made by Dr. Thomas Anderson.



The only mineral I have found crystallised in the cavities is *baryte*. It is in minute crystals of the form figured. It also occurs in thick veins, with cockscomb crystallisations.

Occasionally the acicular tufts of velvet-like crystals above referred to are disposed on the reniform surface of the Göthite in so segregatory a manner as to suggest that they may be a different substance.

At Gleann Thorcaill, the head trench of the Sandside burn, about five miles to the south of this locality, and nearly in the strike of this bed, there is either a fault or a crushed syncline of the rock. It is here a quartzose fine grained granite, and it carries traces of pulverulent *psilomelane*,

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Busby, in his "Minutes and Observations in the course of a Mineralogical Survey of Caithness," writes:—"The channel of the (stream flowing from) Loch of Clachningill (LochnanClach Geala) is composed of decomposed granite, chiefly white quartz. Found at rear of the above, the black oxide of manganese of considerable purity imbedded in decomposed red granite; it is an irregular vein." As this lake is less than a mile from Gleann Thorcaill this may be the same vein, or even the same spot may be referred to.

Busby also states that the red granite of the Ord contains "several large veins of the spar of lime, the crystallisation is thomboid bevellio," ? rhomboid bevelled; ($r\ v$ or $r\ w\ \lambda$).

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Reviews and Notices.

Axinite from Bethlehem, Northampton County, Pennsylvania.
By B. W. Frazier. (*Am. Journ. of Science*, December, 1882.)

THE author in this paper shows that a close relationship exists between the crystallographic characters of axinite and those of datholite. The axial lengths closely correspond, and a comparison of angles between similar planes shows a remarkable agreement. These two species are found, moreover, to correspond in habit as well as in angles. Both minerals are silicates of lime and contain boracic acid, and it is very probable that the morphological resemblance is consequent upon a resemblance in chemical composition. T. J. G.

Silver Amalgam from the Sala Mines.
(T. Nordström, *Jahrb. f. Min.* 1882, 2 *Ref.*, 361-362.)

THIS mineral was found at Sala, in dolomite with quartz and blende. With this exception amalgam has never been found in Sweden.

Composition—

Ag.	Hg.	Fe.	Zu. Pb.	$CaCO_3$.	Insol. gaugue.
46·80	51·12	0·81	trace	0·21	1·01

Total 99·45.

T.J.G.

Alaskaite, a New Bismuth Mineral.
(By G. A. König, *Jahrb. f. Min.*, 1883, 1 *Ref.*, 25-26.)

THIS mineral was found with tetrahedrite and copper pyrites in Colorado. Colour lead-grey to white; lustre metallic. S.G. = 6·878.

Decrepitates on being heated, and melts without the formation of a sublimate. Decomposes in hot hydrochloric acid, leaving a residue of silver chloride with copper pyrites and barytes.

Composition—

	Sb.	Bi.	Rb.	Ag.	Cu.	Zu.	S.
1	—	51·49	12·02	8·08	8·00	0·26	15·72
2	0·51	46·87	9·70	7·10	2·85	0·64	15·07
3	—	51·85	17·51	8·00	8·74	0·20	16·21

T. J. G.

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Analysis of Fergusonite from Burke County, N.C.
(By Prof. MALLET, *Am. Journ. Science*, Nov. 1882.)

THIS mineral was found to exist quite abundantly in placers of the Brindletown gold district. The occurring form is a very acute octahedron, with basal and hemihedral planes. Colour, brown-black, and crystals mostly covered with a gray crust, the faces hardly smooth. S.G. = 5·87. (Smith.)

	Mallet.		Smith.
Nb_2O_5	48·78	... ...	48·12
Ta_2O_5	4·08		
$SnO_2 + WO_3$ ...	·76		
Y_2O_3 &c. ...	37·21	... ...	40·20
Ce_2O_3	·66		
$Di_2O_3 + La_2O_3$ ...	8·49		
U_3O_8	5·81	... ...	5·81
FeO	1·81	... ...	2·75
CaO	·65		
H_2O	1·62	... ...	1·50
	99·87		98·38

The Burke county Fergusonite is thought to be identical with Shepard's Rutherfordite, described from the same locality many years ago on a very small amount of material.

Notes on the Geology of Hong Kong.
(F. W. EASTLAKE, *Nature*, Vol. XXVII., 177.)

IN 1843, Dr. Abel determined the main structure of the island to be of basaltic trap, granite, siliceous and schistose rock. Mr. Kingsmill, in 1865, in his papers on the Geology of the Kwangtung Province, was the first to notice the trachytic porphyry of Victoria Peak (1823), the summit of which overlooks the town. This trachytic rock has been apparently forced upwards through the granite after the overflowing and partial hardening of the trap on the west side of the island. It was Mr. Kingsmill also who explained the nature and formation of the pseudo-boulders, with which the island is so plentifully covered. Towards the extreme south-east, near Cape d'Aguilar, these pseudo-boulders assume very large dimensions, and their weather-beaten aspect proves that the chemical action of the water and plants, which forced them from the parent rock, occurred a long time ago. Indeed the island must have undergone great changes in course of time; the hills beyond Shekko, for instance, must

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have been originally nearly or quite as high as Victoria Peak, whereas its present elevation is not more than 500 feet. The rapid action of the heavy rains and rich vegetation is nowhere more apparent than in the high hill (directly back of the peak from which the colony takes its name) known as the Hog's Back or High West. Its eastern slope is literally covered with pseudo-boulders, rendering the ascent from that side not a little dangerous, and in the rainy season large masses of rock are borne down into the valley beneath. Now that the population has increased, amateur geologists and mineralogists have found silver in small quantities, also galena, lead, and iron pyrites; slate near Aberdeen, syenite and dolerite on a cliff overlooking the one-time piratical rendezvous, Saiwan, feldspar and grey mica abundant.

One of the most interesting finds is that of Molybdenite, near the village of Saw-ki-van. Molybdenite was not known hitherto to be among the mineral products of China. Germany, Sweden, and Cornwall are the chief localities for this rare mineral, and it has been found in several parts of the United States. The South China specimens show all the well-known characteristics of European molybdenite—colour lead-grey, streak the same; thin foliated hexagonal plates, closely resembling graphite; flexible, non-elastic laminæ H = 1·2, G = 4·5. A local chemist corroborated the determination by analysis, and found the composition to be—

Sulphur ...	...	=	40·0
Molybdenum ...	...	=	60·0
Molybdenum Sulphide			100·0

The mineral was found in small lumps embedded in the granite.

T. J. G.

Two new Aluminous Mineral Species, Evigtokite and Liskeardite.
(W. Flight, *Journ. Chem. Soc.*, March 1883.)

Evigtokite.—This mineral, described as "fluoride of aluminium," and obtained from the cryolite bed of Greenland; it came with eudialyte, Arfvedsonite, columbite, black cryolite, Fergusonite, sapphirine, garnet, Allanite, &c., all from that locality. The whole mass consists of the same mineral, unaccompanied by any associated minerals; it is made up of congeries of minute white transparent crystals, mostly broken up, and lying entangled amongst each other, which gives the mass an appearance of opacity much resembling that of kaolin or chalk. The hardness is very low.

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Heated in a glass tube gives off water, and then hydrofluoric acid, with a strong acid reaction; the mineral does not melt. It was pounded, and dried over sulphuric acid, and was found to have the following composition, when the loss in weight is taken to be water:—

				Equivalents.
Aluminium...	16·23 ; with fluorine...	33·64 =	49·87..	0·59
Calcium ...	22·39 „ „ ...	21·27 =	43·66..	1·12
Sodium ...	0·48 „ „ ...	0·33 =	0·76	
			94·29..	0·68
Water			5·71	
			100·00	

These numbers, it will be seen, correspond closely with the formula—

$$Al_2F_6,\ 2\,CaF_2 + 2H_2O.$$

The question suggests itself, may this body have been produced by the action of water containing lime sulphate on cryolite?

The author observes that no mineral described in Dana, or in the recent Paper of Josef Brandt (Annalen, Band 218) on the composition of minerals of the cryolite groups, corresponds with this mineral in composition; therefore the author proposes to give to it the name Evigtokite.

Liskeardite.—A white crystalline mineral with a slight tint of blue or greenish-blue; it occurs as a layer, sometimes a quarter of an inch thick, generally of a uniform fibrous structure, lining hollows or encasing quartz and other minerals. Found associated with earthy chlorite and quartz, iron pyrites, some copper pyrites and mispickel being disseminated in the lode material. Scorodite, in boss-like aggregations, also occurs with it; and at least in one instance the interior of the bosses of scorodite is filled with the mineral in question.

Analysis gave—

Ferric Oxide	7·640		
Alumina	28·229		
Arsenic Oxide	26·962		
Sulphuric Oxide	1·111		
Copper Oxide	1·027		
Lime	0·719		
Water at ordinary temp....	4·351		
„ 100°	10·972	(six equivalents)	34·053
„ 120°	5·551	(three „)	
„ 140°—190°	8·220	(seven „)	
„ with Lead Oxide...	4·969		
	99·741		

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These numbers corresponds with the formula—

$$R''' AsO_4 8H_2O$$

When R represents aluminium, with a notable quantity of iron. The tint of the mineral seems to be due to the presence of about 1 per cent. of copper oxide; and a small amount of a sulphate is also present. The presence of the sulphate and the general character of the composition would lead one to place it with pitticite, or "eisensinter," but the formula is so nearly that of an arsenical, instead of a phosphatic Evansite, that the true place of the mineral seems to be near the Evansite of the late Dr. Forbes. The author has determined the amount of water which left the mineral at several temperatures with great care.

It lost in a vacuum, over sulphuric acid, at ordinary temperatures, 4·722 per cent. or four atoms of water.

It lost, at 100°, altogether 11·266 per cent., which is about eight atoms of water.

It lost, between 100° and 120°, altogether 4·892 per cent., or four atoms of water.

It lost, between 120° and 144°, altogether 3·435 per cent., or three atoms of water.

It lost, between 145° and 160°, altogether 2·448 per cent., or two atoms of water.

It lost, between 160° and 190°, altogether 2·851 per cent., or two atoms of water.

The mineral was then heated with an excess of pure lead oxide in a current of dry air, and the water collected in a calcium chloride tube. The number obtained was a further loss of 4·896 per cent., or four more atoms of water.

The so-called Ersbyite from Pargas. (By F. J. Wük, *Jahrb. f. Min.*, 1883, 1 *Ref.*, 189; *Journ. Chem. Soc.*, May 1883.)—The author contradicts his former statements with regard to ersbyite (*Naumann's Mineralogie*, 1881, p. 672), and he now, after exhaustive investigation, determines the genuine ersbyite to be microcline.

Composition:—

SiO_2.	Al_2O_3.	CaO.	K_2O.	NaO.
66·18	19·52	0·36	13·03	0·91 = 100

S. G. = 2·57.

The colourless felspar formerly mistaken for ersbyite is a variety of andesine, the analytical results being as follows:—

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S_iO_2.	Al_2O_3.	CaO.	NaO.	Loss in Ignition.
59·59	26·44	6·23	7·12	0·61 = 99·99

S. G. = 2·67. (T. J. G.)

Analysis of Emerald from Paavo in Finland. (By F. J. Wük, *Jahrb. f. Min.*, 1883, 1 *Ref.* 189.)—This specimen was surrounded by a zone of radiated red albite, this again by a thin layer of muscovite.

	SiO_2.	Al_2O_3	GlO.
I.	66·37	19·29	14·0 = 99·67
II.	66·10	18·59	14·18= 99·87 (T. J. G.)

Analysis of the Diorites of Montreal. (B. J. Harrington, *Jahrb. f. Min.*, 1883, 1 *Ref.* 247-248.)

SiO_2.	AlO_3.	FeO_3.	MnO.	TiO_2.	CaO.
40·95	16·45	18·47	0·88	8·39	10·58

MgO.	K_2O.	Na_2O.	P_2O_5.	Loss on Ignition.
6·10	1·28	4·00	0·29	8·84 = 100·63 (T.J.G.)

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The Geognosy and Mineralogy of Scotland.

By Professor Heddle.

SUTHERLAND.—Part VI. (*Conclusion.*)

The Marbles of Assynt.

Having, since the date when the few observations chronicled in a previous number were made, ascertained some more definite facts with regard to these marbles, I now note these.

The localities in which I had previously observed the marble were all (through faulting and intrusions) so obscure as regards its relationships, that any conclusion as to its horizon was not warranted.

The discovery of a singular structure imbedded in the marble, led to my again taking up the inquiry, with the result that I found new localities where it existed, and am now able to speak definitely as to its position, at least as regards the chief mass.

The difficulty in arriving at any conclusion with regard to the marble at most of the localities where it is seen, is due to three circumstances :—

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first, to its being so highly altered that bedding and lamination have, as a rule, alike disappeared, or are only, at one or two spots, imperfectly indicated by the occurrence of layers of agglutinated masses of serpentine or of malacolite; second, to its being, where exposed, so corroded into tortuous and fantastic forms through rain-action on its more soluble laminæ, that the eye is at fault in endeavouring to satisfy itself as to the former relative connections of the several masses; and third, to subterranean waters having so sapped out the more calcareous and purer beds, that no inconsiderable portion of what is beneath the surface is in a carious condition, and the surface in the neighbourhood of the marble and even of the dolomite, having given way in all directions to fill up the ever-recurring voids, presents little else than a maze of grassy undulations, sudden pitfalls, and shattered rock. The visible rock is, from this last cause, tossed about in all directions, with a total obliteration of all readily decipherable relationships.

Any one who examines the dolomite throughout its myriad layers, and at its numerous exposures, will note two facts;—the first, the occurrence in it of beds markedly more crystalline than others, and especially of one bed, generally of a cream colour, which is more lustrous on its fractured surface and harder than is the main bulk of the rock;—the second, that whatever its precise relationship to the dolomite may be, the marble evidently bears *some* relationship to it; for, if they be not found in contact, they occur not far distant from one another.

Again, it is found that the marble always has the quartzite as its associate, though that association is frequently physically separated by a fault.

When we inquire what other immediate associates of the marble are seen, we find a peculiar igneous rock in an affluent which flows from Creag-a-Chroisk into the Ledbeg river,—and the Logan Rock, which towers above it where it occurs at the foot of Ben Bhrachaid. To these I have now to add two other rocks,—the so-called quartz-porphyry of Cnoc-na-Strome, under which the marble either plunges, or which has been thrust against or perchance poured over it; and, secondly, the lowest great bed of the diorite of the dolomite, which, in two localities, I find distinctly to underlie the marble, though not immediately.

The above facts taken together constitute, as I have before written, strong grounds "for holding the marble to be merely the altered dolomite."

As it was most desirable to have more to rely upon than merely *strong grounds*, I devoted some time lately to an endeavour to trace the highly crystalline bed of the dolomite into actual contact with the marble, with

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the result that I lit upon localities which left no question in my mind as to what the marble represents.

Marble is laid down in my map of Sutherland at some spots in the neighbourhood of Lynn, on the Ledbeg river. These localities, being in close proximity to the rock of Cnoc-na-Strome (up to the present maintained to be igneous), were examined anew.

Immediately south of the river, and opposite to Lynn, there is a knoll of quartzite which when seen from the road appears to dip under Cnoc-na-Strome. But this is an optical delusion, induced by the steepness of the slopes of the hill; for a little dell separates all the visible rocks.

This dell contains marble, with some loose masses of a very singular pale grey rock, the chief, indeed the apparently sole component of which has a strong resemblance to a massive labradorite.

North-eastward of this, the marble appears near the stream; and here its true position is immediately apparent, as the locality is the site of a very extensive quarry in which a second channel has been cut for the stream. This channel leads to the foot of an artificial cliff or quarry-face, which exposes the main mass of the marble. This marble has a pure white colour banded with blue.

Some eighty yards higher up the stream than the cliff, the whole section is laid bare, partly by the stream and partly by quarrying. From east to west it reads :—Quartzite,—argillaceous beds, here very thin,—dolomite,—diorite,—dolomite,—marble, of a fine puce colour,—dark grey dolomite,—white marble with narrow blue striping, and lastly grass cover. The rock to the west and at a higher altitude is quartzite. The dip is W.S.W. at about 18°. Both the puce and the white marble were worked, and the workings show clearly the relations of the rocks.

Up to the grass cover all is clear. The superiority of the quartzite to the rocks mentioned doubtless will be objected to by those who maintain that there is no upper quartzite; and some who are unable to lay theories aside when observing facts, might exclaim "a fault!"

The writer inclines to the opinion that the circumstances *with difficulty admit* of the explanation that a lateral thrust from Cnoc-na-Strome (if igneous) might have brought up a roll of the lower quartzite, in an anticline between the marble of the cliff in the stream, and the marble of the little dell. Such a roll would be similar, in its relationship to the dolomite, to the anticline of Braebag. However, as no truncated beds of the lower dolomite, nor of the very persistent bed of diorite are seen, and as the quartzite first appears *as an escarpment* which faces N.E. and not as a roll, and as moreover neither dolomite nor diorite is to be seen on either

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of the flanks of the quartzite, the simplest reading certainly is that there *is* an upper quartzite. This is, however, by no means a locality which will strongly fortify any one in maintaining the existence thereof; still less is it one which entitles any one to assert that there is either fault or smash. *The fact of the marble being a bed in the dolomite series, this locality, however, makes perfectly clear.*

Crossing the Ledbeg river at this quarry, and passing a short distance northward, a small stream will be found descending from the south slopes of Beinn-an-Fhuarain. In its channel the "diorite" will be found in force, causing a small cascade, then a short space of flat grass cover succeeds, and next the marble. This may be traced in a linear succession of corroded outcrops for about one and a half miles round the hill, and along its east side; while the "diorite" will be also found coursing round along with it, always dipping under it, and being underlaid in turn by the quartzite of the foot of Braebag. This band of *marble*, as it courses north, gradually loses its saccharine character; it ultimately disappears in a line of water-filled sinks, out of the northern continuation of which the *dolomite* of the N.E. shoulder of Beinn-an-Fhuarain as gradually makes its appearance. On the south and east flanks of this hill, therefore, the marble occupies the place of the dolomite, into which it apparently gradually shades off. Both dip on every side into and under the hill; and both are overlaid on every side by quartzite, which quartzite in turn is overlaid by a red grit.

Such are the grounds upon which I hold that the marble is a metamorphosed bed of the dolomite.

In considering what may have been the agent of the metamorphosis, it has to be noted that the change ceased as the bed passed northward.

Glancing at the map it will be observed that all the localities where the marble occurs lie round, and nowhere at much greater distance than a mile from the quartz porphyry of Cnoc-na-Strome,—or from the spurs of this hill.

Beyond the fact that immediate proximity vouches for the marble of Ledbeg being the same mass as that seen in the little dell above described, little can be said of the relationships of that particular mass. In the stream channel it is seen faulted against quartzite; while at the more northerly of the spots where it protrudes from the overhanging hill-slope it is again in contact with quartzite, here thrust up in a quâquâversal dome.

The mode of occurrence of the singular structure found in the marble has now to be noticed.

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The localities are the central and the more northern of the three masses which lie on the hill-slope above Ledbeg.

At the first of these localities only one portion of it is seen. It presents itself as a dark band stretching nearly horizontally from W. to E. in the marble. This band has a length of 16½ feet, a thickness of 4 to 5 inches, and it extends into the rock for a depth of at least 3½ feet. It lies in the rock in gently undulating folds. At one spot it throws off an arm or process at an angle of about 15°. This branch or arm was about 2 feet in length and about 8 inches thick. At another spot it threw off a short process at right angles.

Its exposed surface was much corroded by the weather, and its structure was thereby unfolded. That boldly displayed structure consists of gently plicated but very rough layers of a substance which evidently was less soluble in rain-water than had been that whose removal left the layers protruding. The appearance of this exposed surface is precisely that of the representation of eozoon given by Carpenter, in the last edition of his work on the microscope; and the colour is very much that of printer's ink. When broken into the rippled structure stands out to the eye in bold relief of blue-black upon a nearly white ground; this is mottled with granules of yellowish-grey.

Occasional patches of greenish-yellow granular precious serpentine occur; there sometimes are nodules of this the size of the fist, and it occasionally is milk-white. It must be noted that the aspect of this dark band as a whole is in no respect that of a siliceous band in a primary limestone; but, in its isolation, and in the abruptness of its margins, is altogether that of an imbedded structure.†

At the second mass of marble the same structure is seen, appearing here as an erect vein in the marble, the bedding of the latter being almost horizontal. This vein is 8 or 9 inches in thickness. This also goes to show that the structure as seen at the first locality is not a mere band of highly metamorphosed material.

The structure of this fabric, when seen under the microscope, appeared

† In a late discussion at a meeting of the Geological Society (of Edinburgh?—Ed.) upon this marble (called Dalbeg), it was observed by one of the speakers that it occasionally "*became* eozoic." As this phraseology indicates transition, or gradual passage, it is necessary to remark that it is altogether misleading, so far as I know of it. Whether the structure be the outcome of the action of the marble upon one included fragment of gneiss or not, it has to be noted that there is no gradual passing of the one into the other,—no *becoming*. A line of demarcation, sudden and sharp, is present all round the periphery. Black at once succeeds to white. The thing is, as I stated to the Royal Society of Edinburgh, very like one of the boas worn by our grandmothers, and still liker to one of the dried whale cutlets seen in Farös.

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to me to be so similar to eozoon that I placed it in Dr. Carpenter's hands for examination.

Dr. Carpenter writes of it:—"The general conformity of your specimens and of some of the Canadian is so close as to leave no kind of doubt of their being the same thing."

The matrix, material of, and the minerals associated with this structure, have now to be noticed.

At Dr. Carpenter's request I analysed the matrix of the structure, that is, the rock in which it and the minerals found with it are *immediately in contact*.

Dissolved in moderately strong acid with the aid of gentle heat, it yielded—

Carbonate of Lime	46·307
Carbonate of Magnesia	37·632
Carbonate of Iron	1·022
Carbonate of Manganese	·368
Soluble Silica	·700
Insoluble residue	14·408
	100·437*

The insoluble matter, examined with the microscope, was found to consist of rounded crystals of malacolite, with small quantities of serpentine, quartz, margarodite, and magnetite. As this analysis differed much from that published by Dr. Anderson, I thought it necessary to examine a portion of the rock at some distance from those imbedded or included masses.

As pure and typical a portion as possible was, therefore, during a recent visit, broken out some distance away from them, and an average sample of its mass analysed, that is, not the purest white part thereof picked out, but chips from the whole when crushed up were taken.

There was got:

Carbonate of Lime	55·562
Carbonate of Magnesia	39·942
Carbonate of Iron	·358
Carbonate of Manganese	Tr.
Alumina	·306
Soluble Silica	1·481
Insoluble residue	4·238
	101·851

* The carbonic acid was not determined. Doubtless some of the lime and magnesia had been in combination with the soluble silica.

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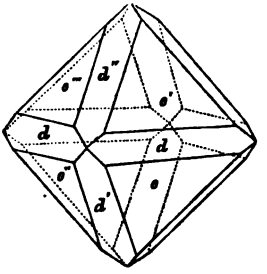
The carbonic acid was not determined. About 2 per cent of the lime and magnesia must be in combination with the soluble silica. The insoluble matter consisted totally of crystalline granules of malacolite.

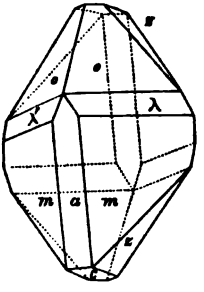


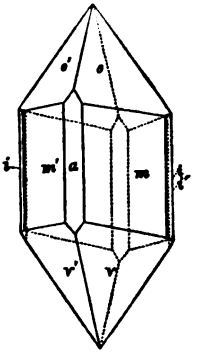
The greater part of the structure itself is formed of dark serpentine with some *magnetite*. The latter is occasionally in octahedral crystals, and more rarely in that form with dodecahedral truncations. The crystals are highly lustrous, and are energetically polar.

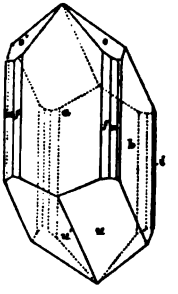
Margarodite is mixed with the magnetite.

Pale ochre-yellow *malacolite* is present in large quantity, in granules. These are generally rounded on the angles, as is so frequently the case with minerals imbedded in a calcareous bed which has been subjected to the extreme energy of metamorphism.

The malacolite is, however, occasionally well crystallised in the three types figured—*m*, *a*, *c*, *o*, *d*, *z*, generally without *d*;—*m*, *a*, *o*, *v*, *i*, and







without *i*;—*m*, *a*, *o*, *u*, *f*, *i*, and without *i*. There are also, more frequently, simpler forms. The crystals are very minute and are associated with small rock crystals.

Colourless,—opaque white,—sulphur green,—and black serpentine also occur.

The surface of much of the white marble is rough as a rasp. This is due to the protrusion, above the general surface, of crystals which have evidently proved less soluble in rain-water than has the general mass of

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the rock. The lens can without difficulty make out that these protuberant crystals are saddle-shaped. They are found to be soluble in strong but not in weak acid; and a mass of the rock placed in weak acid leaves undissolved a vesicular structure composed of these, with smaller quantities of malacolite.

An attempt to conduct separate analyses of the crystals, and of the portion of the rock dissolved out by weak acid, failed, on account of the acid attacking the more insoluble crystals to a certain extent, during the solution of the general mass. All that could thus be ascertained was that the readily-soluble portion contained very little magnesia; while the more insoluble seemed to contain the whole of the iron, and nearly all the magnesia.

This fact of the separate crystallisation of the magnesian portion of highly metamorphosed dolomites is interesting, and significant of a great amount of mobility of particles. In virtue of this condition of crystalline intermixture, doubtless different portions of the rock will vary in composition.

The marble thus is a metamorphosed ferruginous dolomite. Dr. Anderson's analysis, previously quoted, may be explained by supposing that an unusually calcareous portion had been put into his hands; or even perhaps a portion of a calcitic vein of the rock.

In announcing at the Royal Society of Edinburgh the discovery of the singular structure seen in this marble, I indicated that its microscopic appearance seemed to me to show structure *not mineral*. Lately, however, the examination of numerous slices made me doubtful as to the correctness of that view, and induced me to enter upon an exhaustive examination of it. The result has been that, as regards the inferences to be drawn from the appearances which I first noticed, I have entirely altered my views.

I have endeavoured to represent in the plates (Plates VII. and VIII.) the various structures present in a slice of the dark belt, as seen with low powers. I shall indicate these as the *lenticular*, the *subfibrous*, the *ovoidal*, and the *serpentinic*.

Of these the first consists frequently of rudely lenticular sections of crystals the size of a pea, of a carbonate which is soluble only in acid of medium strength. When lenticular, the crystals are somewhat curved at both extremities in opposite directions. They are intersected by two sets of parallel markings which cross with a major angle of about 85°. One set of these markings polarises with brilliant colours with the lower Nicol alone; the bands of colour being of variegated tints, and not of any one uniform colour from end to end. As another portion of the rock is soluble in much weaker acid than are these crystals, and as in fact these

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crystals when examined separately are found to be highly magnesian, they are to be set down as the dolomitic portion of the marble.

The question now is, are these bands of colour due merely to the polarised light being analysed by a thin film of air in the cleavage rents on the crystal,—or are they due to twin plates of extreme tenuity,—laminæ lying in the crystal parallel to the face $-\frac{1}{2}$ R, such as in certain specimens of Iceland spar were shown by Brewster to be the cause of the variegated plates of colour therein seen? As a thin film of air would, at its portions of greatest tenuity, exhibit a series of rainbow bands, and as the second set of markings, drawn in in black, may be seen to be cleavage rents, which do not analyse the light, there can be little doubt that the coloured striping here seen is due to thin plates; and though dolomite, there is perfect identity here with the lamellation seen in Carrara, and other marbles.

The portions which I have termed the subfibrous are the most transparent, and apparently the hardest portions of the slice. They are devoid of regular form, and are about the size of mustard seed. Even without the analyser they faintly show a fibrous structure. This the analyser shows to be intermediate between divergent and plumose in arrangement. The delicate hair-like crystals shoot generally from only a single spot in the surface of each little nodule, passing through its substance in gentle curves, as if they had grown into a cavity. The appearance differs only from that of filamentous augitic-serpentine in not being straight-acicular and radiating. Acted upon by weak acid, the fibres are left protuberant, and then appear white, and of silky to brilliant lustre. They fall to powder, and are ultimately almost totally soluble in strong acid.

As the most highly soluble and truly calcareous portions of the rock surround these fibrous nodules, they may, after the brief action of very weak acid, be picked out.

Operating upon a very minute quantity, I found them slowly decomposed by weak acid with slight effervescence; and readily disintegrated and almost totally soluble in strong acid. In the solution I could only find silica and lime.

The fibres thus seem to be *Wollastonite*. This is not uncommon in the marbles of Scotland. It is stellate-fibrous in rents of the limestone of Allt Ghoiridh in Skye; and in rents of diorite in Barra Hill, Aberdeenshire. It is radiating fibrous at Delnabo in Glen Gairn and Crathey quarries. Matted and interlacing at Corntullock, on the Dee.

The plumose appearance here is different.

From the shooting of the fibres from only one or two isolated points,

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they certainly have more the appearance of having grown into a cavity than of being a substitution product of change; but the *shape* of the little masses is not that of casts of a cavity; they are too angular. And, if cavities were once present, the evidence is all against their having been *tubular* cavities, for, however cut, they show much the same form.

The ovoidal masses were those which at first sight seemed to me to depart furthest in appearance from mineral structure; after due examination their structure is the most evident of all.

At the first glance they resemble sections of tubes, the centres of which have been filled up; looked at with more care they resemble rings of oil. Processes are next seen to connect the opposite sides of the ring, which processes pass through the substance of the central material. There is more or less of parallelism or rectiliniarity in these transverse processes, and where they are frequent, there is more or less of a prevailing angle in the intersections of the different sets which traverse the central material.

These connecting processes leave no doubt as to the ovoidal masses being either olivine or augite in a condition of change.

In fact they present an admirable, though a miniature illustration of the special appearance of the transmutation of the less ferruginous *augites* into serpentine, as contradistinguished from that of *olivine* into serpentine.

That which here caused the recognition to be tardy, is the extreme roundness of the grains of *malacolite*.

These grains from their occasional yellow colour were at first considered by me to be *chondrodite;* but while figuring the crystals, I perceived how frequently they were rounded, and, picking a sufficiency from the residue of the solution of the marble, I found that they contained no fluorine, and were grains of malacolite, which were greasy on their surfaces from partial conversion into serpentine.

The dark green to black blotched and marbled serpentinic structure,—which has here and there, when examined macroscopically, a wonderful resemblance to the delineations of eozoon, and also it must be said to a rippled gneissic structure,—more resembles in appearance the lozenge angularity of serpentine formed from olivine. It is thus possible that olivine may have been here present, though olivine is unknown in Scottish dolomites. A structure very similar is, however, seen in other rocks, as in gneiss from Unapol, dolerite from Loch Assynt and Schiller spar.

Professor Lapworth, after an examination of some of my slides, pointed out a delicate arborescent dark green structure as one which called for

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special study; this is only seen by the employment of a high power, and can have little bearing upon the structure generally termed eozoic.

From the above examination, while admitting that I am unable to explain the peculiar disposition of the fibres of the Wollastonite (?), I have to say that I see in this marble no structure that is not referable to mineral arrangement, and none which, so far as my knowledge goes, is referable to animal structure.*

The plate shows at 1. the *Malacolite* and *Wollastonite* (?) portions of the rock; at 2. the *Serpentinic*. The other structures shown are those of rocks which resemble this last structure. 3. is Hebridean gneiss from Liverpool; 4. dolerite from south shore of Loch Assynt; 5. Schiller spar from Belhelvie.

In the banks of a stream which descends from the east side of Creag-a-Chroisk the marble is found enveloped in a dyke of an igneous rock of very unusual appearance. It consists for the most part of a pink felspar, in which brown garnets are imbedded. In section these are red, and are cinctured by a

Marble, which the writer cannot discriminate from that above noticed, sweeps round the hill east of Loch-a-Meallain on the south side of Strath-na-Sheaskink, and comes into close proximity with the series of carbonates, considered Upper Limestone by Sir R. Murchison. These occur on the east slopes of Cnoc-a-Chaorninn.

This marble can be traced so far west on the north side of the hill, that there can be little doubt that it is related to, though it does not appear to be connected with that already noted as lying on the south of Ben Bhrachaid. It is distinctly separated from the "upper limestones" by a band of quartzite; but its close proximity will doubtless, notwithstanding this fact, be founded upon by those who maintain that the "upper limestone" is merely an inversion of the dolomite.

In controversion of such a view the writer has to state that he has entirely failed to find the yellow argillaceous beds at either of the localities where he has seen the "upper limestone." He has also failed to find, at either, a trace of any of the beds of "diorite" so characteristic of the

* It may not be out of place that I should here state, that after having unravelled the structure of this Scottish eozoon, I thought I was to a certain extent in a favourable position for entering upon an inquiry into the nature of the Canadian, to which it was said to bear so great a resemblance. I cannot say that my specimens of true eozoon are at all good examples, being merely those usually sold; but of these, such as they are, I have just to say, that in them I saw nothing which I did not see in the Scotch; that I did not in them see so much; and that nothing that I did see did I see nearly so well.

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dolomite; but he finds in the "upper limestone" of Loch Ailsh an albitic porphyry, very similar to, if not identical with, that which is characteristic of the upper quartzite.

As regards the beds of these "upper limestones" themselves (of which it is much to be desired that we had analyses), neither in structure nor arrangement do they seem in any way to resemble those of the dolomite, beyond this, that one of the beds at Rhieknock is *somewhat* similar to the thin upper crystalline bed at Knockan, but similar to it only at the spot where it is there subjacent to crushed schists.

A widening out of the system may bring this "upper limestone" (itself dolomitic) into the same series as the dolomite, but that it consists of the beds of the latter *inverted*, is at present mere unsupported speculation.

In fine, whatever evidence of an inversion of the dolomite series there may be elsewhere, the writer has to say that between Glen Coul and Loch Borrolan he has not been able to note a single fact which bears out such inversion, but that every fact which he has observed in any way bearing upon it is opposed to such a view. If no inversion can be shown *here*—no matter what can be shown elsewhere—the existence of an upper limestone, as maintained by Murchison at Loch Ailsh, and found by the writer at Rhie Knock, will have to be admitted.

In maintaining, however, that the dolomite as a whole is not *inverted*, I must be understood to mean that *as a formation* it dips regularly *under the rocks which succeed it to the east*; and is not cut off from them by any such fault as claimed by Nicol, so as to form a ⊐ shaped trough, (a trough the age of which can in no way be disclosed by the rocks in its proximity).

I have already stated that, though in certain localities fractured at its eastern fringes, the dolomite forms a trough in the Maoloch Corry district; and that I believe it once swept over the double anticline of Braebag, and was succeeded to the east by the overlying Logan Rock of Ben Bhrachaid. Again, in the Beallach of Braebag Tarsun it can be seen with the underlying yellow beds curving over the east side of the Braebag ridge, at an angle which almost forms a local inversion *to the east*, but it immediately rises again, and on the N.E. side of the pass is conformably overlaid by a thin band of quartzite, which in turn is overlaid in regular sequence by Logan Rock, fine grit, coarse conglomerate, and the quartzite of the top ridge.

Further east, at what may be considered a linking spot between the beallochs of Bhrachaid and Tarsun, namely, in the slopes below Dhu

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Loch More, the dolomite, overlying yellow beds and quartzite, is again seen with a very low dip, conformably overlaid by a thin band of schistose quartz, this by a fragmentary felspathic and argillaceous grit *which passes into Logan Rock through the gradual augmentation in thickness of interstitialised bands of hornblendic material.*

This Logan Rock, as will be after fully described, ascends into the precipices of Ben More, and is regularly succeeded by quartzite,—the giant grained conglomerate of Coineveall being here absent. It is indeed a feature of the upper quartzite that its several and very distinct members are disposed in lenticular masses. Whether they be grit, conglomerate, or Logan Rock, they come in suddenly, in wedge like form, and as suddenly thin off; and this they do both along the strike and dip. Now, on the west side of the Braebag ridge the quartzite is seen to be thrown into two folds, the more easterly so abrupt as to constitute a small local inversion of some of its beds; and what is a mere fold at one locality, may certainly present itself, if the returning fold be shorn off, as a great inversion at another. But what the writer maintains is, that the returning folds of one or other member of this system of rocks will, in this district at least, be found dipping under the eastern gneiss;—that the state of matters is not to be represented by the letter ⊐ lying at any angle, and *separated by a fault* from the eastern gneiss, but, that it may in certain disturbed localities be represented by the letter *S*; the drooping summit of the *S* being *regularly overlain by* the eastern rocks, although the upper part of the fold is sometimes cut off. At some localities, as at Knockan, the overlying rocks are immediately those of the eastern gneiss; and where at other localities the immediately overlying rock is quartzite, or is Logan Rock, there is nothing anomalous,—for these rocks, where present, lie *between the dolomite and the eastern gneiss.* There is certainly nothing more anomalous in the fact that these rocks should come in, in such manner, in this district, than that they should do so elsewhere. That they do so come in, will be seen by any one who will walk from Dundonnell to Kinlochewe, keeping himself rigidly to the junction the whole way.

The Red Grit of Ben-na-Creisaig and Ben Fhuarain.

Cunningham left these hills uncoloured in his map; the writer purposed doing the same in his own map, and it was only some scanty observations which induced him to allow the colour-tint assigned to quartzite to remain, after it had been too hastily assigned to them.

The superiority to quartzite and to dolomite of the red rock which forms the summit of both of the above hills is evident; and the fact that both

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dolomite and an intervening band of white quartzite dip towards and apparently under the red rock from both west and east, forming a small basin, is also evident. But it must be admitted that the simple conclusion to be drawn from this fact must not hastily be jumped at, as there is some faulting at the south-east corner of Ben-na-Creisaig. (Marble and an igneous rock dip under the south side of Fhuarain, and dolomite is separated only by a thin fringe of quartzite from the rock of the north side of Creisaig, but the dip is here obscure.)

Again, the nature of the rock is so very different from the quartzite in its general appearance that the desire to see it somewhere else than in mere outliers is strengthened, the more it is examined.

The rock is a loose red grit composed of tinted quartz with some uncoloured grains, and a good deal of fragmentary felspar. So far it resembles the Torridon conglomerates; but the resemblance goes no further. It contains none of the granules and fragments of jaspers, vein-quartz, and other siliceous foreign-matters so common in the Torridon rock, and its appearance as a rock mass is altogether dissimilar. Instead of being disposed in great sheets of ever-varying structure and size of grain, which weather readily into loose and crumbling slabs, this is an even- and thin-bedded rock; vitrified in appearance, and enduring. It breaks with a clinkstone ring, its beds are not readily separable, and it splits up, not into a loose gravel as does the Torridon, but into sharp-angled fragments.

It was the finding, in the trench of the Cold Stream Burn, *masses of worm-hole quartzite firmly rivetted to the under surface of this highly metamorphosed and sometimes almost flaggy rock* which convinced me that it was a member of the upper quartzite, characterised, as patches of the upper quartzite are here and again, by special local peculiarities. The passage here was an absolutely insensible one as regards the sand grains, but there was a sharply-defined change of colour.

Some appearance of a west and east fault, with a downthrow on the south of the limestone with its cover of white quartzite and red grit, induced me to re-search the north-west face of the opposing Craig-a-Chroisk for a grit similar to that of the two hills. About the N.W. corner of this hill, in the same relationship to the limestone, a thin bed of just such a grit is found; the only distinction I have observed between them being that the last mentioned is somewhat looser in structure, and not of so deep a colour.

Now, as we course southward along the outcrop on Craig-a-Chroisk this bed of grit is about 200 feet below the shoulder of the hill, and that shoulder as we approach Cama Loch consists of Logan rock. The slope

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is for the most part grass clad, but in some of the bared spots the actual contact is seen. Passing up to the summit, quartzite is found overlying the Logan rock.

The section here reads, Hebridean gneiss—quartzite, white and purple—yellow beds—dolomite—grits with pyrrhotite, others with serpulites—Logan rock—quartzite. This, with the exception of the non-occurrence of the Hebridean and of the serpulites, is also precisely the section at Dhu Loch More. I would, therefore, correlate the grit of Ben-a-Creisaig with the somewhat more felspathic grits of Dhu Loch More.

When we consider the manner in which purely local beds of varying characters, markedly circumscribed in dimensions, appear in the series of rocks which have been referred to the upper quartzite, I conclude that the facts of the case justify us in referring these two outliers to that series also.

The Logan Rock.

Though this rock has been noticed before, chiefly in the description of the map of Sutherland, its detailed consideration has been deferred, in order that the several rocks to which it has been by different writers referred, with their accessory minerals, might have been described. The question of its relationship to one or other of these being thereby necessarily in a fairer way of being answered.

I have already shown how diverse and irreconcilable are the views entertained regarding this rock. Four recognised authorities hold it to be igneous; two maintain that it is upper gneiss; one that it is Hebridean gneiss faulted up; and one that it is "an old gneiss" somewhat altered.

The views entertained as regards its position by dissentients from the last contention, are more or less accordant with one another. All place it in close association with the quartzite, with the exception of Dr. Hicks, who puts it between the quartzite and a series of rocks which he conceives to be still more recent.

There was in the original view of Mr. Hudleston more latitude and caution than in that of Professor Bonney, for he did not commit himself to the *Hebridean* gneiss but only to "an old gneiss;" and such a reading would have been far from unacceptable in comparison to some of the others, at least as regards certain districts and some problems connected with these which are somewhat involved.

Mr. Hudleston, however, has lately departed apparently entirely from such a construction of his words, for, in a late discussion of the subject,

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he writes:—"Although, therefore, there are certain differences in the aspect of hand specimens, and still more perhaps in the general character and behaviour of large masses, yet the "Logan" rock appears to me to possess more resemblance to the Hebridean gneiss than to any other formation in the district. There must be differences, however; otherwise so acute an observer as Nicol would hardly have continued to call this rock "granulite," "syenite," "diorite," according to the district he was describing. In Assynt his "Logan" rock is mostly "syenite," and he appears to have regarded it as intrusive.

It is probably owing to the circumstances connected with its appearance in the position now occupied by it in the Assynt mountains, and largely also to partial injection by local extravasations and to crushing during folding, that the main points, in which the "Logan" rock differs from ordinary Hebridean gneiss, arise. And yet I hesitate whilst writing this, bearing in mind that Dr. Heddle, who knows both rocks so well, does not perceive the relation, which always struck me as subsisting between the two, though I am far from saying that they are absolutely identical."

But if not identical,—what? There is the whole question.

Mr. Hudleston says that I do not perceive the "relation;" and looking above to see *what the relation is*, we read "possesses more resemblance to the Hebridean gneiss than to any other formation in the district." Now I readily grant this. The "relation" is but a *resemblance* after all; all along I have seen a resemblance, sometimes a marked resemblance; but I see something more than this; I see also points of distinction which, when all things are considered, are still more definite than those of the resemblance.

In a chronicle of the state of our knowledge of the geognosy of a country it is well that as small an amount as possible of mere theory should be intruded; but as this rock has at present to be regarded as a most critical one, it is necessary that the chronicler should do something more than merely enumerate and describe the sections which he has visited, the rocks which he is prepared to say that he has recognised, and the minerals which he has, or has not, found. I have examined this rock in more localities and to a greater extent than any other in Sutherland and Cromarty, and have in speaking of it said that even after an "extent of walking very inadequately vouched for by one hundred and seventy-seven thousand feet of climbing, I did not feel myself in a position to pronounce upon its *precise nature*." Still, while assuming the position of being unable, from the very varying features which it assumes at different

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points, to give it a definite name, I am prepared to say *what it is not.* I have made every attempt to remove my own difficulties by trying to fit in the theories of its being the Hebridean rock faulted up at this spot, folded back by an inversion at that, or thrust in like a wedge at that other,—disregarding, in the so doing, all other discrepancies.

I have in another consideration of it, with all due liberality, given every latitude to metamorphosing and altering processes, augmented in energy by squeezing, crumpling, and fracturing. As the outcome of all, I have to say that, though probably *made out of it*,—as the younger is ever made out of the older,—it is not the Hebridean gneiss, and is not even of the same age as the Hebridean gneiss. I hold, that stratigraphically is is *impossible* that it is so; geognostically it is *incredible;* lithologically it is *inconceivable;* and mineralogically it is *improbable.*

Truly, in Macculloch and Cunningham, Murchison, Ramsay, Harkness, Nicol, Geikie and Hicks, Messrs. Bonney and Hudleston are attacking a goodly phalanx; the numerical preponderance of which will be some measure of the honour which must accrue to them should their view prove the more correct.

But there are two circumstances connected with the conclusions arrived at by two of the members of that phalanx which well might have "given pause" to any one in coming to an opposite opinion. I allude first to the fact that Murchison (who may be said to have instituted the Hebridean gneiss as a formation,—insisting upon the regularity of its bedding and the dominance therein of a prevailing strike), did not or could not recognise this rock as the same; but throughout, when speaking of it at many localities, connects it with disturbance. Secondly, to the fact that Nicol, who saw such a resemblance between the western and eastern gneisses, that he maintained that they were one and the same, expressly, at every point where he noticed it—(and no one noticed and pored on it so much)—*excluded this rock from the category*, describing it as different from both, and giving it specific and distinct names, according as its features varied. In the so doing, Nicol expressly excluded it from the inversion on which he insisted.

Nicol, it should be remembered, superadded to the skill of a geologist, the knowledge of a mineralogist.

Numerous, however, as are the authorities who hold that this rock, as seen in Sutherland, differs from the Hebridean gneiss, they are not in number equal to the localities occurring out of Sutherland (localities unquoted by these authorities), which also bear witness, and far more clearly and emphatically than do any in Sutherland, to the distinctiveness

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of the two rocks. These localities will be noticed in the consideration of the county in which they occur.

In speaking of this rock it is needful to state that I am far from asserting that the Hebridean rock nowhere appears in the long stretch between Loch Carron and Whitten Head;—there are in fact two masses,—the wedge-shaped mass north of Ben Uidh, and a small one in the Corry Dubh of Braebag,—which I desire again to examine:—it must be understood that my remarks apply to the rocks which occur at the localities which are specially noted.

In considering the features of this rock, the physical and petrological may be taken first.

It may be remembered that in speaking of the Hebridean gneiss, I stated that its most marked feature was the distinctly segregatory arrangement of its component minerals, and their invariable highly crystalline condition; that its divisional plans were so marked, with often an approach to an actual separation, that they came to be lines of weakness, into which waves and rain could make their way. The opposite of all this obtains as regards the Logan rock. It is true that at certain localities, it is in a certain sense crystalline in structure, but this is not the rule; and whether it present itself with a crystalline structure or the opposite, there is alway a marked blending and inter-fusing of its mineral constituents.* So uniform is this *mass-mixture* of ingredients, that one of the difficulties connected with this rock is that, except at junctions, it is difficult if not impossible to make out bedding, dip, or even such structure as enables us to say what the very nature of the rock is. Mr. Hudleston writes, "one of the most difficult tasks is to make out any definite system of divisional planes, which might be regarded as showing the bedding." This distinction is very characteristic.

When we stand upon a glaciated surface of high tilted Hebridean, we feel our tackets† gripping a rough gritty rock; while parallel stripes of strongly contrasted colours pass away from the eye in gently rippling and closely adjacent lines.

A glaciated surface of the Logan rock again is dangerously smooth, looks like coagulated mud, in clotted lumps, while its coloration is in utter confusion. In some places a blotching of red, green, and white; in others, a mass of twisting and interlacing lines.

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* Well seen in the rock of Glen Logan, where the intermixture of the red and white felspar is such that Mr. Hudleston pronounced the former to be oligoclase.

† "Tackets," anglice "boot-nails."

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Nor do these highly contrasted rocks lie far apart. One of the localities claimed for an inversion is Loch Glen Coul. The two rocks—*one* according to the inversionists,—do not lie a mile apart on the south shore, and under three hundred yards on the north. The Hebridean gneiss is seen upon the south shore of the Loch, so perfectly and regularly bedded that a boat can at almost any spot run safely ashore along the jointings, and its occupants step out, as at a pier. The dip is at a low angle to the W.N.W., and the waves have found so ready an entrance into the jointings, and between the beds, that blocks fit for building purposes lie pitched about. Such blocks in fact, have, without any dressing, been employed for building the piers at the Ferry of Kyle Sku. The Logan rock again, where first seen at the head of the Loch, protrudes from the turf in rugged nobs, in which neither bedding or jointing can be seen. Half-way up the ridge which forms the ascent to the stack of Glen Coul, the Logan rock which forms that ridge, is glaciated into smooth contours, which should well disclose its structure; but no recognisable bedding is seen, and it has so uniformly coherent an arrangement of its parts, that a chip or specimen can only be procured by attacking some protruding corner. Here the lineated structure—the convoluted serpent-like folds,—point down the loch; that is at right angles to the strike of the lower rock. As regards inversion here, the lower rock dips the wrong way,—presenting fractured out-crops towards the supposed trough; while, again, any *indications* of bedding which the upper rock presents, are at right angles to the direction required for an inversion.

Nicol was censured for supposing inversion possible between Kean-na-Binn and Hope Lodge, a distance of nearly five miles; but the distance on the north shore of Glen Coul is only a few hundred yards!

As regards the segregation of its components, the feature of the rock is that it is in the main concretionary, and not linear; and where tending to linear, it is highly tortuous and involved. Its constituents are a hornblende which is not so dark in colour, or so lustrous by any means as that of the lower gneiss; not so crisp-crystalline and foliaceous, but mere short-flakey, or as Mr. Hudleston calls it, "thin banded and matted." "A hackly pinkish felspar," instead of the yellowish-brown, flakey, and pearly-lustred orthoclase of the Hebridean. Both of the above minerals are minutely sprinkled and spotted with interstitial quartz and oligoclase.

But the marked constitutional feature of the rock is the almost invariable presence of the so called "*epidosite*." This is palpably a secondary product, as it occurs invariably in veins, which ramify into rents which are

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often disclosed only by its presence. This large amount of epidosite I regard as one of the characteristics of the rock.*

There are two other features—constitutional features—one of which, at least, distinguishes it still more. This is the occurrence in it of *belts*—(I cannot call them by another name, as I am unable to say that they are beds)—of varying thickness, from 1 yard to 20 or more, of a substance which differs much from the main bulk of the rock. This is a fine-grained, dark brownish-green, muddy-like rock; hardly dense enough to be called aphanitic. This is interlaced throughout and to a marvellous extent by extremely thin veins of epidosite (?). In the hill of Glasven there are numbers of these dyke-like bands, the first three, at least, of which have a strike parallel to the line of outcrop of the underlying dolomite and quartzite. These bands sometimes seem to tilt the obscure beds of the inclosing rock, while in the Coire Laich of Coineveal the same rock occurs not in clearly defined belts, but in masses nearly as large in amount as the Logan rock itself. Now this dark green rock, dense and uniform in structure as it appears to the lens to be is, when a section is made

* Mr. Hudleston writes, "I have usually been disposed to regard the abundance of epidosite as one of the features of the "Logan" rock which especially distinguish it from the Hebridean gneiss: but Dr. Heddle states that this peculiar *mélange* occurs in greater quantity, and perhaps in a purer state in the west of Ross-shire than in any locality known to him. This is in the Hebridean gneiss near Poolewe. Hence this presumed distinction vanishes."

But Mr. Hudleston here writes in misconception of my meaning. If my description of the Hebridean gneiss be turned to, it will be found that, *in speaking of the substances occurring therein*, I referred to a substance which occurred in "*some districts*;" which substance I conceived to be the same as one described by Macculloch as found in the western gneiss, and which he thought green felspar. *That substance* I said I had found in greater quantity at Poolewe than at any other spot where I had got it. My analysis of the Poolewe specimens proved a failure, but enabled me to draw certain conclusions. I knew that Dr. Macculloch considered it a felspar; I also knew that Mr. Hudleston had applied the term *epidosite* to a similar substance got in the Glen Logan rock, and I wrote, "I conclude that the thing as a whole is that *mélange* which has been termed epidosite." "I shall, therefore, with a *caveat* term it mean-while epidosite." I also stated or indicated the reasons for the caveat, namely, that both the Loch Maree and the Harris specimens showed incipient crystallisations of recognisable *epidote*.

Now this may not be distinctive between the substances occurring in the two rocks; but so far as my experience goes the substance from the Hebridean *always* shows incipient crystallisation; while in no one of the many slices which I possess of that occurring in the Logan rock, have I ever seen a trace of this. In all the slices the green matter passes into and through quartz, like the fibres of an untwisted cord, or as a cloudy stain. Be this as it may, instead of occurring as do the veins of the substance found in the lower rock, only *in some districts*. epidosite occurs everywhere throughout the Logan rock; and though I have not yet found it in perhaps quite such thick veins as those in which Macculloch's "felspar-like mineral" is found at Poolewe, yet it is present in certainly a very much larger total amount.

I therefore go quite along with Mr. Hudleston in being "disposed to regard the abundance of *his epidosite* as one of the features of the Logan rock, which especially distinguishes it from the Hebridean gneiss." Hence Mr. Hudleston's "presumed distinction" does *not* vanish, but it is fortified.

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at right angles to its surfaces of contact with the inclosing rock, shown by the microscope to consist of a highly-contorted "chloritic" schist, of a very minute structure.

The second distinctive feature is the frequent occurrence in it of dykes of a dark, large-crystalline, igneous rock. This consists of augite and a grey plagioclastic felspar, probably labradorite. The crystals of these minerals are often arranged in an orbicular manner, like *Napoleonite*. The spheroids are about the size of marbles, and they are very evidently disclosed on the surface of the rock by the radiation of the crystals of the felspar, which are whitened through weathering. Neither of these rocks, I need hardly say, have I seen in the Hebridean.

Such are the ordinary lithological features of this rock. It might, however, be said, that an ordinary feature is *the extreme abruptness with which there is a change in the relative amount of its constituents*, but as this feature pertains most markedly to the *different beds in which it occurs*, the detail of such varieties is left to the description of them.

A geognostic feature, however, now claims attention. I have above admitted *resemblance* between portions of the two rocks. I shall admit further, namely, that it might be possible to select specimens—though not typical specimens—of the two which could not readily be distinguished; but still I say, with all assurance, that no one whose eye has, by traverses from Kishorn to Erribol, been educated into a recognition of the features of the landscape presented by the surface-weathering and vegetation-covering of the two, can fail to recognise at a glance appearances which are special to each—so special, indeed, that we are able at a distance of one or two miles to pronounce without hesitation as to which rock lies before us.

The features of the landscape of the Hebridean gneiss I have described:—a tumbled mass of little hills, sharp-angled in their outline, like petrified waves of the sea. Macculloch, speaking of them in detail, and of the numberless little lakes which are clustered among them, declares that there is not one of them which does not contain the fundamentals of beauty. This could hardly be so were they not more or less grass or heather clad; and this is, in fact, the feature of the surface of the Hebridean rock. Rock, dark in colour, protruding every here and there, form a covering in which grass at one spot and heath at another prevails.

Grass is almost unknown on the surface of the Logan rock. Heather, even, is but rarely seen. Bare rock—generally rounded or trenched by ice—sprinkled with boulders,—its internally deep colour blanched to a grey yellow through the weathering of its felspar, shows itself in an endless

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series of undulating contours, and presents a surface of such extreme barrenness that, when compared with it, the Hebridean rock looks fertile and warm.

The contrast is well seen in descending the slope from Glasven to Kyle Skou. The Logan rock on the north shore of the Loch is nearly vertically disposed over the Hebridean, with only a double belt of quartzite intervening.

"The very face of the country is different. The underlying rocks *cannot* be the same," I heard a geologist exclaim when first looking across the water. The contrast is still more marked eastward of the head of Loch Coul, and between Ben Uidh and Rhie Knoc. Ice has here scoured off what little vegetation may have once clung to the crevasses or the hollows. In the midst of these lie gloomy lakes cut off from all sunlight, and a scene of such unrivalled desolation is presented that the locality has not inaptly been termed "the Valley of the Shadow of Death."

Such are the petrological distinctions between the two rocks. The mineralogical may be dismissed in a sentence.

Of the Logan rock the record is a blank.

I have searched this formation to a much greater extent than any other in Sutherland, and I have never found a crystal or a simple mineral in it. Nineteen species were enumerated from the Hebridean gneiss of Sutherland alone, several occurring in abundance. When we come to Ross and Inverness shires it will be found that several others have to be added, but neither in Sutherland or in any county in Scotland have I found a single mineral in this rock. It will be indeed difficult to show how the faulting up of a rock, or its inversion, could abstract from it all the substances which had once crystallised therein. It is quite rational to suppose that crushing, rending, and churning up with limestone fragments might, through evolved heat, produce *new* minerals, but that such operations should abstract pre-existent formations is altogether incredible.

Its *constituent* minerals sometimes, though rarely, approach, but no more, to a definite form. I found a mass of graphic granite, about the size of a man's head, at Liath Bhad, Glen Coul; and Mr. Hudleston picked up a weathered fragment, in which the skeleton crystals of quartz were larger in size, in Glen Coul itself. The hornblende in the little cliff which faces the west on the extremity of Ben Bhrachaid is somewhat actinolitic; it is fibrous, and of a leek-green colour. Minute specks of *pyrites* rarely occur in one of the beds at Camer Loch.

This is the only rock mass I ever examined in which I have found no minerals.

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Localities of the Rock.

The most southern locality at which this rock appears in Sutherland is along the north-east shore of Cama Loch. The section from the west to the east-end of the lake, reads as follows:—

At the west-end we find the Hebridean gneiss with its usual appearances of distinct linear arrangement of constituents,—well seen in some glaciated islets in the lake. Weather action has, through partial abstraction of the felspar, exalted the appearance of parallel banding of the hornblende and quartz. To the north-west the huge cone of Suilven stands as an islet of Torridon sandstone, the basement beds of which stretch as a flat pediment for nearly a couple of miles eastward of the head of the lake. Walking along the north shore, we tread upon the upturned edges of the lamination of the gneiss. The exposure of its internal structure is excellent, but no epidosite is seen. About a mile from the head of the lake one of the basement beds of the Torridon-foot of Suilven, distant nearly a mile to the north, sweeps suddenly southward from Cnoc a Vuic, crossing our path. It dips to south-east at about 8°, and thrusts itself as a small cliff, a few yards in width, into the waters of the lake. Upon its eastern side the Hebridean again appears, and extends for some hundred yards, when it is overlain immediately by the quartzite.

Beds of this rock, abundantly riddled with wormholes, are passed over until the mouth of the Allt-a-Chroisk is reached. Here there come in, conformably to the quartzite, hard and dense beds of the argillaceous rock, with "fucoids;" the dip being 11° to east-south-east. The fucoids are here less carbonaceous, but much thicker and more massive in structure than is usual. A steep-sided grass-clad knoll overlies these beds. Upon its summit alone is any rock visible; that consists of protuberant masses of a highly typical variety of the Logan rock. Only by trenching could it be determined whether these masses are or are not *in situ*. To the eye they look loose; to the hammer they do not sound so. The knoll terminates a shallow trench; it is thus possible that it may be but a heap of morainic matter. Morainic heaps are seen about the fourth of a mile to the north-east. Such are the facts which speak to this being a "dirt heap." Those which speak against it are:—

1st. The shape and surface-dressing of the knoll are entirely different from those in its vicinity; and different moreover from the usual appearance of water-dressed morainic matter.

2nd. No rock is seen in the knoll but Logan rock, although the stretch of ground which would have cradled a glacier should have yielded Torridon conglomerate, quartzite, fucoid rock, and dolomite.

3rd. The glacier-trench consists to much the greatest extent of quartzite, only a feeble fringe of Logan rock of a different variety from that seen in the knoll occurring; moreover, no masses of the variety seen in the feeble fringe of Logan are seen in the knoll.

4th. The variety which alone forms the knoll, does not occur elsewhere in the neighbourhood. It is well described by Mr. Hudleston who took specimens, he writes: "I hold a thoroughly typical specimen of "Logan" rock obtained from the somewhat isolated exposure to the west of Ledbeg. It is striped something like a tiger, with bands of a hackly pinkish felspar, partially relieved by dull white quartz alternating with thick or thin bands of a dark-green matted hornblende. The cracks and backings are lined with abundance of pale green epidosite, which is so characteristic of the rock in the Logan valley. Altogether this is a fair specimen, though there are others far richer in quartz."

5th. This same variety occurs in the Meallan Laoigh in Ross-shire, immediately overlying the fucoid bed.

I conclude from the above that this knoll consists of loosened, but not displaced, fragments; and the disrupting agent may have been a glacier.

A close grained vitreous and much fissured quartzite succeeds. It is seen along the shore of the lake, where the eastern end of the quartzite bed forms a small cliff. The dip is about 9°.

Immediately overlying this there is a bed of about nine feet in thickness of Logan rock of a type quite different from that just described. It is close grained, the individual crystalline aggregates being about the size of peas; has a dull brick red colour passing to yellowish brown. The lustre is greasy or waxy, and it is slightly trans-

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lucent. It consists chiefly of orthoclase with little quartz, very little foliated hornblende, and still less epidosite, which is present in externally thin but closely ramifying veins. Altogether this rock is very similar to the so-called quartz porphyry of Cnoc-na-Strome. Quartzite with the same dip succeeds; this bed is less vitreous in appearance, and less fissured than that which underlies the red Logan.

This quartzite is succeeded by a thick bed of Logan of ordinary appearance, that is the green, red, white, and colourless ingredients are present in about equal amount; but epidosite here dominates largely in some parts of the bed. It is of an unusually brilliant green colour, and uniform fine grained structure. It is occasionally blotched by thin scales of a brilliant red substance, in which the lens can recognise no structure. The thin plates of this red substance are disposed parallel to the sides of the veins. The veins which are in some spots half-an inch in thickness, are purer in appearance than any I have seen elsewhere.

Quartzite succeeds as far as the point of the terminal bay of the lake, when the next bed of Logan is seen. With the exception of its under and upper surfaces which contain both quartz and white felspar, this bed is composed entirely of matted crystals of dark green subfibrous hornblende, with a few lacings of epidosite. It weathers out in rounded lumps of about two cubic feet in size; and, did not its surfaces and some few veins show its nature, it might be called hornblende rock.

Quartzite, coarser in grain, again succeeds for a short distance along the shore of the little bay; this is overlain again by a bed of Logan rock in which the constituents are smaller in individual particles, and more mixed through one another than usual.

Keeping the same line, the east shore of the lake is now quitted; and just above it to the east-north-east, we come upon a little cliff of flinty quartzite overlying the Logan rock. This bed of quartzite is about 14 feet in thickness, and is overlain conformably, and still at about the same angle, by a mass of Logan rock which stretches to and across the road from Elphin to Ledmore, and along the roadside, so long at least as any rock can be seen. Again is the feature of the rock changed. By many it would here be called granitic or syenitic. It is in appearance like a harlequin's coat, so far as colour is concerned:—a spangling mass of white, red, and green, the red, which is brilliant, predominating, and it is laced throughout by epidosite.

There is a flat space of about two hundred yards between the last seen rock, and the banks of the Ledbeg river which is covered,—and if we may judge by the banks to be seen to the north, and the gravel beds of the river, the cover consists of drift. The rock next seen is immediately upon the east end of the bridge, and it is highly characteristic, though its characteristic features are possibly due to a modification of pseudomorphic alteration. In structure it resembles the westerly dull red bed of Logan, but it has a brown colour, blotched with dull greenish grey. It has a waxy lustre, is translucent, and the greater part of it cuts easily with the knife. It consists of a muddy dull red felspar, in rude crystals, imbedded in a substance which is *identical* in appearance with the pseudophite from Plaben, Budweis.

The rock as a whole is very similar to the lower bed of the Logan rock which I have afterwards to note as occurring at Liath Bhad; the size of the component crystals is here, however, somewhat larger.

As the substance which is similar to pseudophite is peculiar, and as it gives to the rock its unusual appearance, it was particularly examined.

To the eye it looks like congealed suet, sprinkled here and there with glistening scales.

Under the microscope it polarises feebly, showing a structure like ground rice; and is altogether very similar to the pseudophite of Beauty Hill in Aberdeenshire.

Its specific gravity is 2·804.

On analysis by an assistant, it yielded—

Silica	44·803
Alumina	36·050
Ferric Oxide	4·804
Lime	·407
Magnesia	·675
Water	13·835
	100·574

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2·9 per cent. of the water was given off at 212°; and 2·58 per cent. of the silica was insoluble in boiling solution of sodium carbonate.

This is a massive *kaolin*.

In an imperfect analysis of the lustrous flakes imbedded in the massive mineral, there was got—

Silica	44·217
Alumina	33·373
Ferric Oxide	4 388
Lime } Magnesia }	lost
Water	6·917

This looks like *euphyllite*, but there were no alkalies; and I question the possibility of separating this substance sufficiently from its matrix to make the analysis reliable.

If the first noted substance be merely a product of alteration, it is very difficult to say what mineral has been changed into it. It certainly is deserving of being re-examined. All that I am able to say of the rock is that it conveys the impression that it is an intermediate between the last seen Logan rock, and the next seen,—the quartz-porphyry of Cnoc-na-Strome.

No junction can however be seen; at least I failed to find one in the bed of the Ledbeg river. The rock-banks are here so rotten and air-wasted, that actual quarrying alone would suffice to reach an unaltered portion.

Though, however, no junction can be seen, there is not, in the nature of the surface, anything which indicates a break in the succession between the rock at the Bridge and the rounded domes of Cnoc-na-Strome and the hills to the east of it.

Exception must be strongly taken to the name given to the rock of these hills.

No true porphyritic structure can be seen in it, and of its two ingredients,—felspar and quartz,—the former is decidedly that which shows traces of crystalline form. The quartz, indeed, is frequently altogether absent. The rock, in fact, is nothing else than a mass of agglutinated granules, of the size of peas, of a more or less brilliant red felspar. The information derived from microscopic examination is altogether unsatisfactory, for the felspar of even the apparently freshest masses is clouded and without character; there is an obscure meshwork in some parts, with interstitial quartz, which usually falls out during the grinding down of the slice.

It might be hoped that a mass of rock over 800 feet in thickness, and some miles in length, would show some appearances either of bedding or of flow; all that is seen is very obscure. A structure something like bedding, but more like the convoluted structure of the Logan rock, is seen on the bared summits of the hills; and this structure runs from north-north-east to south-south-west, and has an almost vertical dip, instead of the low dip seen at the junctions of the Logan rock. But, again, the jointing of the cliff faces of the northern side of the hill indicates a rude bedding conformable to the dip of the quartzite beds at their junction with the Logan rock.

This rock stretches eastward to about the centre on the hill east of Loch Borrolan, and almost up to Loch-a-Meallean. Here it throws off a well marked spur to the north-east (Khie Cnoc), which apparently connects it with the mass of Logan rock of Ben Bhrachaid. Eastward of the little lake, the rock is in appearance intermediate between that of Cnoc-na-Strome and the Logan rock; with here and there a great resemblance to the rock seen at the Bridge of Ledbeg; at other points there is some slight resemblance to an igneous rock. The rock of the east end of the hill is again like "Logan" of a red hue, and a grey-brown labradorite-like bed is the last seen.

To the east of this hill marble is found—the bed sweeping round the hill to the north-west, with no evident dip. After crossing the road to Loch Ailsh we have the section which discloses the supposed upper limestone.

Of the above sequence it has to be remarked that at the point westward of the bridge where the ground was covered, if not at a second point, we lost all true hold of the section; and that it is very probable, seeing that there is disclosed elsewhere an evident semicircular sweep of the whole series of rocks, that we may, after the crossing of the bridge, have been walking *along the strike*.

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Before leaving this eastern and obscure portion, however, it may be well to consider what the rocks there seen really are.

The earlier geologists all term Cnoc-na-Strome *quartz porphyry*, and the hill east of Loch Borrolan they called *gneiss*.

In speaking of the localities of the marbles, I noted the fact that these were all more or less adjacent to the dome of Cnoc-na-Strome or its off-sets. Giving all due weight to that fact, I have yet to say that I incline strongly to the opinion that the red rock is a mere variety of the Logan rock. I would not *now* even go so far as to regard it as a volcanic rock which had broken through the "Logan" and incorporated portions of it,—though that was my earliest contention with regard to it.

If we consider the marked variation in character in the successive beds of the "Logan,"—if we consider what is disclosed to us in other parts of the country, namely that the Logan rock comes in with extreme suddenness, forming masses or lumps which are lenticular when considered either along the strike or at right angles thereto,—if we remember the close resemblance of this "quartz porphyry" to the red bed on Cama Loch, and the apparent passage of the "porphyry" into Logan rock eastward of Loch Borrolan,—and when we come to know that Scoonan Beg and Sail an ruar come in (equally red with Cnoc-na-Strome) to form the connecting-links of the Logan rock between Scoonan More and Meall-an-Aonaich,—I conceive that we are justified in deciding that the red rock may prove to be a mere variety of the "Logan." It certainly does not depart in appearance or in simplicity of components from the ordinary variety of that rock, to a greater extent than does the hornblendic belt which is sheathed, and no more, in recognisable "Logan" on the shores of Cama Loch.

As bearing upon the section seen along the shore of Cama Loch, it has to be stated that at but a small distance northward of the shore exposure (above described) the Cnoc Ledbeg rises in a steep and craggy face, which exhibits the different beds as they sweep round the angle of the hill to be exposed on its west face continuous with Cnoc Led Vuie, in the true line of their strike. The alternation of these beds can thus be seen and proved to exist a considerable way back from their exposure on the lake shore.

The height of the Cnoc is not such that its western or its south-western cliff contains the whole of the enumerated beds, at any one spot; but, by starting from the shore line at any one bed and scaling the opposite cliff, all which lie above the selected bed are passed over, with the exception of the easternmost which sweeps round on the eastern slopes of the Cnoc.

Starting for instance from the first little quartzite shore-cliff, we pass over the red bed just above its summit, then traverse a low hill slope, coming upon quartzite at the cliff foot: over this in the cliff we find a thick bed of "Logan," overlain by a thinner bed of quartzite; and just over the rounded brow of the cliff we come to "Logan" again. All dip into the hill at a low angle. The sequences are similar wherever we scale the cliff as it droops to the eastward; we find successive thin bands of varying types of a rock, which are all structurally different from the great mass of the Hebridean rock which lies but a mile distant. These beds are interbedded with bands of quartzite, more or less vitrified in appearance, which beds show no worm holes, and there is no appearance from top to bottom of argillaceous beds or of fucoids.

When the beds of "Logan" are followed along the strike in the west face of Cnoc Ledbeg, some are seen to thin out, while others seem to assume laminated quartz, and to shade off into quartzy beds. One such bed, seen in the little bealloch between this hill and the more northern Creag-a-Croisk, is stratigraphically apparently a fissile quartzite; but when broken it is seen to contain much felspar which is sprinkled throughout it in such a manner that it has to be pronounced an intermediate. The last bed seen which can be decidedly pronounced "Logan," almost immediately overlies a highly crystalline blueish-grey dolomite, in Creag-a-Croisk. This bed has a bright red colour, and the only petrological difference between it and the Cnoc-na-Strome rock is that it contains some isolated particles of bright green hornblende, and is somewhat more coherent in structure.

Nowhere throughout the whole of the section is there the smallest appearance of slickenside or of folding or crushing. I own myself quite incapable of con-

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ceiving how any system of faults at an angle of 9° could have produced such a structure as that described above; or how any folding over of the beds could have brought back the great solid mass of the "Hebridean" in flakes of ever-varying composition, and could at the same time have multiplied one thick bed of the quartzite teeming with organisms, into five or six thin flinty beds, which show no organism whatever, and this moreover without anywhere revealing a trace of the fucoid bed which is associated therewith at so small a distance as only a few hundred yards.

Northward, along with the overlying serpulite grit, of the section described, the first point where the Logan rock is seen is in Ben Bhrachaid. Meall Diamain to the west, consists of worm-hole quartzite, rolled in so gentle an anticline, that the height of the hill above the valleys on its north and south flanks is probably a near measure of its thickness. The fucoid beds are seen in the col between this hill and the craggy western front of Ben Bhrachaid. I have not seen the dolomite, but as the ground is swampy there may be a wash out. The "Logan rock" succeeds above, with its usual rough and uneven surface, and is succeeded by somewhat flaggy beds of quartzite, the total thickness of which is quite insignificant when compared to the huge masses of Braebag and Meall Diamain to the west. Of this section it has to be said that although the superiority to the "Logan rock" of these thin beds of quartzite is perfectly evident, that of the Logan rock to the fucoid beds is not altogether so. At the actual junction the ground is soft and covered, and screes of loose stones run down the sides of the hill, covering the line of junction on its south side; on the north foot of the hill, however, the quartzite, though it shows a feeble fault about the line of the col, and a still feebler one a few hundred yards eastward of this, is seen to pass under the "Logan rock" for a considerable distance to the east.

Altogether, this is not a section upon which I would found much.

As regards the *nature*, however, of the rock here seen, it must be maintained that it is very different from the Hebridean. The hornblende in the little cliff spoken of, is almost fibrous, and of a greasy lustre; and it is so riddled and cross-hatched by thin veins of epidosite as to have no small resemblance to serpentine.

The Logan rock is now seen to the north. as a band which lies between two beds of quartzite, in Meall an Aonaich, and in Carn nan Conbhairean. As the debris of the quartzite of the summits of these hills has streamed down their southern sides, the junctions are there obscured. I have not examined the north-east sides, where good exposures are to be looked for. The band of rock in both hills is seen to be continuous with the great mass in Ben More.

Passing eastward, two admirable and similar sections are exposed in the streams which issue from the Dhu Loch Beg, and Dhu Loch More. The description of the latter will suffice. Starting from the quartzite foot of Braebag Tarsuinn,—littered with water-dressed heaps of debris which has been swept from the foot of the great escarpment at the south side of Coneveall,—and crossing the head waters of the Oikel, we come upon the yellow argillaceous beds, surmounted by the dolomite, just where the ascent in the channel of the stream becomes rapid. A small cascade in the stream marks the next junction. The cliff of the cascade is the result of the endurance of a bed of cherty rock and of the scooping out of the underlying dolomite. It admirably displays the junction of the latter with its cover, and also the nature of the several rocks. The overlying bed of cherty rock is thin, fine grained, slightly muddy looking, sprinkled abundantly with minute cubes of pyrites, and pervaded with branching seams of flinty chert. As it was of importance to ascertain if this chert could in any way represent the lower quartzite inverted, I separated the flinty bands from the general mass, crushed it up and examined it with acid. There was considerable effervescence, and the solution contained both iron and alumina in considerable quantity, with some soluble silica.

The chert is immediately overlaid by what may be called lithologically a felspathic grit. This is a pinkish yellow, close-grained rock. It breaks with nearly equal ease in three directions, due apparently to the felspathic granules lying much in the same direction. The felspar seems to be orthoclase, and the quartz, present in about one fifth of its amount, is colourless to milky,—and of a vitreous to fatty lustre. Both felspar and quartz are in sharp angled particles of about the size of shot. Under the microscope the felspar is somewhat moulded round the quartz

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fragments, so it must have undergone considerable metamorphism, and is not truly a grit. This rock is exposed for about 100 yards in the bed of the stream, when it is seen to become gradually banded by dark-green belts; these are disposed parallel to the strike of the underlying rocks. The bands are at first pale in colour, from the small amount of green material. This is sprinkled throughout the belts like grains of gunpowder. When the rock is broken into, the dark bands are found to pass under those of pale tint at a dip, as nearly as can be estimated, the same as that of the underlying quartzite and dolomite. The alternate more felspathic belts—still dominant in width—are, in the proximity of the quartzite, quite free from the darkening material, so that the above fact is easily seen. As we ascend in the bed of the stream, the relative dimensions of these beds is inverted; the dark predominating, and also themselves darkening in colour. As the dark bands have proved both less soluble in the water, and less easily worn by the friction of suspended gritty sand and rolling stones, they protrude above the level of the more felspathic portions of the rock, and appear as a series of ridges which mark accurately the line of strike. Wherever broken, the dark material of these bands is found to be crystalline hornblende. By the continued increase of this ingredient the rock becomes typical "Logan;" and, for some little distance above the point where it must be so termed, bands of the pink felspathic character are seen.

Towards the upper part of this series of transition bands, and where the rock would be regarded as more gneissic than gritty in structure, there exists a band slightly more protuberant than the rest. This had been mentioned, and was pointed out to me as a *dyke of basalt*, and was said to cut off abruptly the felspathic grit from the Logan rock, and to break the succession. This band I found to consist in reality of *dolomite* pervaded with augitic matter and somewhat serpentinized. Out of it I broke masses, the size of the fist, of a highly crystalline carbonate. These masses had almost a pearly lustre; and besides the carbonates of lime and magnesia, contained much iron carbonate.

From this point the rock becomes typical "Logan." It extends across the flat which holds Dhu Loch Mure, and rises north of it, as a series of buttressed precipices. It is immediately overlaid by a great belt some hundred feet in thickness of quartzite. This belt stretches unbroken for some miles, being continuous with that on the summit of Coneveall, as well as with that seen in the hills which prolong the ridge to the south-east.

I regard this section as an absolutely conclusive one; it reads, quartzite,—argillaceous beds,—dolomite,—chert,—felspathic grit passing gradually into "Logan" rock, which contained near its base a thin belt of dolomite,—quartzite.

Where can a fault be placed? There is not the smallest appearance of one, nor of anything of the nature of disturbance. The edges of the gently dipping beds are spread out like a pack of cards, and they succeed one another in rectilinear and close-fitting contact.

Above the cherty bed which is elsewhere associated with it, the dolomite is succeeded by a rock which had been once at least fragmentary, which is banded parallel to the lower rocks, and this banding unquestionably unites it in *age* with the overlying rock, whatever amount of question there may be as to the nature of that rock. How can a fault, moreover, account for the appearance in what some hold to be the Hebridean gneiss of a bed of dolomite unknown in it elsewhere?

Then as to inversion. The section at Knockan* establishes the fact that the dolomite is overlain by the eastern gneiss. We should, therefore, on the theory of an inversion, expect to find some reduplicated beds of that series of rocks in the centre of the dolomite; or, on the extreme supposition of the inversion having taken place *before* it was overlain by the eastern gneiss, we should find the supposed inverted fold of the Hebridean overlain by the newer eastern gneiss. The dark rock is, however, overlain by quartzite.

The theory of an inversion posterior to the deposition of all the rocks, demands the reappearance above the dolomite of, first, the yellow beds, distant not many yards down the stream; and, secondly, of the vast thickness of the quartzite of Braebag above these yellow beds.

* And others in Cromarty.

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Such a theory absolutely fails, moreover, to account for the felspathic grit,—for the thin bed of dolomite in the dark rock,—and for the fact of the quartzite overlying the dark rock. The occurrence of such a felspathic rock would have to be pointed to in some part of the extended exposure of the undoubted Hebridean, for it is far from trifling in extent,—stretching apparently the whole way between the streams which issue from the two Dhu Lochs, as a cornice of vertical cliffs 60 to 80 or more feet in height.

In fact, this felspathic grit invalidates faulting and inversion alike; while its occurrence is perfectly in accordance with what has been said above to be one of the features of the Logan rock,—namely, that it varies markedly in appearance in different localities.

If we run a section across the rocks at the east end of the Bealloch of Coneveall, we gain further information.

In speaking of the dolomite I mentioned that a patch of that rock occurred upon the north-east slope of Braebag Tarsuinn overlying the yellow beds, which with the dolomite were thrown at a high angle by the crushed double anticline of that hill. The underlying quartzite, the yellow beds, and the dolomite give us our position definitely in considering the rest of the section. Immediately north-east of the dolomite there lies the deep trench of the Bealloch, on the north-eastern side of which, though at a lower level, another patch of dolomite is seen. As the floor of the trench is covered with detritus it is quite possible that a rent is also concealed. If such exist, it certainly does not break the succession, for the yellow beds are found underlying the dolomite of the north side, and by regarding both patches of the latter from a position which flanks them, it is seen that there is no displacement, but only a medial cutting out of the bed, the line of dip on the Tarsuinn side falling exactly as if extended upon that on Coneveall.

This outlying eastern portion is seen for only thirty-four yards along its strike, but it is regularly bedded and unbroken. This is evidenced by a bed near the bottom of the mass of about a foot in thickness—and of a fine grained structure and pale blue colour; which stretches like a broad ribbon from end to end, unbroken. Over this, the dolomite is of the coarse granulated structure which is the prevailing character of that rock wherever exposed to atmospheric waste. The bed dips at a low angle into the hill. North-east of this bed there is a grass cover for eight yards, when a well-marked and perfectly unbroken bed of quartzite is seen. This has exactly the same dip as the dolomite. The bed is about eight feet in thickness. A heathery sward succeeds for a short space, when Logan rock of the convoluted serpent-like structure comes in as a sort of rounded cliff, which *can be skirted almost continuously along the strike* to a little above the point of transition of the felspathic grit into "Logan" in the bed of the Dhu Loch More stream.

The direct rise, however, on the section from the quartzite, brings us upon a spur of Coneveall which is thrown out to the south-east. Ascending this, it is observable that the Logan rock upon the left, which forms a considerable portion of this face of Coneveall, is rudely columnar, or in huge spheroidal masses, with a slightly radiating structure. Great rhomboidal masses hang toppling, and the whole of this side of the hill has a shattered and ruinous appearance.

Those who are familiar with the great cliffs of the Hebridean will vouch for it that nothing of the kind is to be seen in them. Whatever point of the compass they may face, at whatever angle to the formation they may be cut, or whatever agency may have operated in their formation, all that remains is self-rivetted and enduring. Witness the smooth-faced frontlet of Cape Rath, or its pinnacled stacks; the grand precipice of Ceann Garbh of Foinaven; or the rock-ribbed sides of Ben Stack. Ragged they may be, but never loose or shattered; when ragged they look as if torn out of a mass of hackly but most tenacious iron. Here it is altogether different: the ruin of this rock has induced ruin in the overlying beds of quartzite; and enormous heaps of water-dressed debris, swept from the cliff-foot, are spread for some hundred yards to the south-east,—and that in an amount sufficiently great to resemble morainic heaps. Overlying the Logan rock we find, at an elevation of about 2550 feet, a bed, or rather a double bed, of felspathic grit. The two beds are under six feet in thickness. The structure of this grit is different from that which underlies the "Logan" as seen in the last section; the difference of structure

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depending primarily, if not immediately, upon difference in the relative amounts of the felspar and quartz. Instead of a condition of firm agglutination, this rock is brittle and friable. The quartz grains, coarse in one bed, finer in the other, are greatly in excess; the felspar, though of two colours—flesh and pale white—seems yet only orthoclase. It is in sharp-angled fragments, larger than those of the quartz; and is kaolinised to a considerable depth in the rock. It certainly has the appearance of having been much less metamorphosed than had the lower grit; but this is doubtless due to the felspar granules being so far apart that they could not agglutinate with one another.

These beds have a pale fawn colour. Though so limited in thickness, they are very persistent. They can be seen stretching away to the right; drooping first as they cross the corry between Coneveall and Ben More, and then rising to come to the surface at about the centre of the connecting ridge. To the left they rise, to come to the surface on the north-west slope of Coneveall, but seen to thin off in so doing, as they cannot be found on its western slope. This drooping sweep is nearly along the strike; and the beds are dipping into the hill also, at right angles thereto, at an angle of about 23°.

According to those who maintain that the Logan rock is the Hebridean gneiss, that rock is not held to be (as usual) inverted at this spot, but merely *faulted up*; and these grit beds are regarded as the basement beds of the lower quartzite. This contention goes hand in hand with the view maintained by certain of the opponents of the sequence laid down by Murchison and Geikie,—namely, that it is irrational to maintain that a rock so feebly metamorphosed as is the quartzite could underlie strata which have been altered into mica schists, gneisses and syenites.

Among the many contentions of those presently engaged in a controversy as to the age of these rocks, no one has been more persistently urged, and enunciated with more unhesitating assurance, than *that the quartzite and the associated dolomite are slightly if at all metamorphosed.*

The writer has often been desirous of ascertaining from those who wield the wand of "metamorphism" so jauntily, and are so familiar with its potency, if they could conceive of any circumstances in which it might be inoperative, or were acquainted with any substances which it was impotent to change.

Certainly of late years we have, in this country, been more familiarised with a glib use of the expression *metamorphism* than enlightened as to its mode of acting. We have not, indeed, ever been favoured with facts bearing upon it such as might prove of use to those who so condescend as to make use of facts.

Where have we been presented by those who speak and found on the absence of metamorphism in the quartzite and in the dolomite, with any facts which go to prove their contention?

Where is our enlightenment,—drawn from their knowledge of the composition of the rock,—the presence or absence of cement in its sand grains,—the nature of that cement,—the influence upon that cement of

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heat, pressure, moisture,—the modifications of that influence effected by the varying nature of the overlying rocks? Where are we to look for such a series of investigations, analyses, and reasonings, as those undertaken by Bischoff, Delesse, Damour, before *they* diffidently propounded their contentions with regard to questions infinitely less wide and perplexing than *metamorphism* must long continue to be?

How comes it that when so many scientific men are honestly striving after the truth, it should be so terribly difficult to confess that they have not yet attained to it?

How metamorphism acts, we may not know,—but, *upon what* it can operate, and what it sometimes *can effect*, we do know. Acting chemico-physically, it can change *substances which are capable of change;* and acting physico-chemically, it can bring about the union of *substances capable of uniting*,—if they be present, and be also in contact. But it cannot change the *unchangeable*, and it cannot effect combinations, if one material alone be present.

Silica *alone* is chemically inert; and sand, however much agglutinated, is a chemical residue. In the carbonates of lime and magnesia, again, all the combination-changes which can take place have been effected; if beds of these materials be buried deep in the earth's crust, so that the escape of carbonic acid is prevented, they may be crystallised into marble; but no other physical change of structure has, in these rock masses, been recognised; and, chemically, only the alkaline metals could transmute them. Even granular-silica, however, if it have been buried deep in the earth's crust, has been found to become crystalline, or actually crystallised;—sometimes veins in the latter condition, intersect granular belts: while carbonates which have been buried deep—but such only—are found to have effected a surface-union with the elements of their enclosing rocks; and so, under the guidance and restrictions of chemical laws, have formed definite mineral species.

So universally recognised is the qualification of *deep burial*, that the field mineralogist, when in search for lime-silicates, never turns aside to examine recent rocks;—experience has told him that his time would be thrown away.*

While the writer, not having any particular theory to substantiate, has made no special study of these western rocks as regards the amount of change which they have undergone, still certain facts connected with

* Sir Robert Christison found *apophyllite* in a Coal-measure limestone quarry, at Chapel in Fifeshire; but it was in a cavity, and evidently had been formed through water infiltration.

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them presented themselves to him, which entitle him to say that the statements that the quartzite and dolomite have not been metamorphosed, or have suffered a trifling amount of change, *is a bare assertion*,—the outcome either of insufficient observation, or of scientific ignorance.

Of these rocks it has, in fact, to be said, that while they might have been more transmuted, transmutation has in them gone a long way.

The dolomite, at all points where it is in force and well exposed, shows a crystalline bed;—where impurities have been present in the bed, these now appear as crystals of augite, as at Coire Chaorachain, &c.;—and where the altered bed has been thick, as near Ledbeg, it is a perfect marble; and there *malacolite*, *Wollastonite*, and *magnetite* appear in the mass of the rock; with *serpentine*, *pyrrhotite*, and *lime-felspar*, at the lines of contact.

As regards the quartzite,—along the whole south face of Ben Harran and the slopes of Coneveall, it is so markedly crystalline, that the sand-grains have become crude crystals of quartz; and all around the tarn which lies south-west of the summit of Na Tuadhain, there is every here and there a passage into masses which are collections of small doubly-terminated prisms of rock crystal. These are sometimes nearly a fourth of an inch in length. Here also, brecciated portions of the rock are cemented by hard, dense, massive *psilomelane*. But the evidence of the metamorphism of the quartzite is much clearer in the two beds of grit found near the summit of Coneveall, than at any other point known to the writer. A section of the apparently loose grit (mentioned as there occurring in two beds), shows the "sand-grains" not *agglutinated* to one another, but *interlocked by mutually interpenetrating, sharp-angled "processes,"* which vouch for a certain amount of softening and recrystallisation; and the line of contact of the "sand-grains" has at some parts disappeared, and at all has become faint.

The fluid-cavities are arranged in two ways. A number of semi-angular particles of orthoclase (?) are sprinkled through the stone; lines of fluid cavities start from the rounded angles of these, and radiate therefrom through the "sand-grains." Other lines of fluid cavities stretch from side to side of the stone, passing through the sides of the sand-grains at all angles.

Numerous minute doubly-terminated crystals of transparent pale brown *zircon* occur. The size of these bears a certain ratio to the size of each grain of quartz. Though not absolutely central in position in each grain, they are never found at the sides. No large crystal occurs; no chip of a large crystal is seen, and the small crystals are never broken.

The inference is unmistakeable. The fluid cavities were not pre-

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existent to the fracture of the grains of silica; they were formed at a date posterior to the agglutination of the grains. The zircons crystallised out of the silica *after* it had been fractured into grains; and at the time of their formation, the substance of the silica had been so yielding that the crystallising force was able to draw the molecules of zircon through it to the common centre of the crystallising effort. The arrangement of the fluid-cavities in lines, shows that this plasticity was posterior to the re-agglutination. The amount of metamorphism to which the quartz had been subjected, after it was reunited as a number of "sand-grains," would appear to have been even greater than it had ever been subjected to before the processes of fracturing had torn it from the parent crystal.

Thus is it seen that the view that the dolomite and the quartzite have not been metamorphosed is altogether untenable.

Overlying this highly instructive fragmental grit, there are beds of coarse and of fine grained conglomerate. In that which is coarse, the included nodules are rarely sub-angular,—generally much rounded and smoothed. Frequently they are themselves brecciated, the fragments being re-cemented.

They are all siliceous, and of more or less brilliant tints, in which purple prevails. They vary in size from that of marbles to that of turnips. Some are apparently vein quartz. The cement is green, of varying tint, and it is pearly in lustre; it is disposed in a general parallelism to the floor of the bed, being plicated where it folds over to envelope the nodules. This cementing material is so similar in all respects to that of a bed, shortly to be noticed, which underlies and passes into the Logan rock, that the writer could not undertake to discriminate between them. At those parts, moreover, where it contains felspar, it is hardly to be distinguished by the eye from Logan rock; and it cannot be distinguished by the microscope from certain varieties thereof. This rock, as a whole, has a dark green colour, spotted with purple and white.

The fine grained bands are more of the nature of a grit. There is in these little or no foliated cement. The granules are the size of seeds, and frequently show false bedding. Here and there they contain flakes of the green mineral along with blotches of felspar, with some hornblende; where this is seen it is difficult to discriminate between these bands and the Logan rock.

The representative of the fragmental bed appears, I believe, elsewhere; but I know no other locality in Sutherland where this conglomerate is seen; it is merely a local basin,—vouching for deposition on a very uneven bottom.

A band of very even-bedded quartzite of several hundred feet in thickness, overlaps the grit and conglomerate both to east and west,—rising to the summit of Coneveall, and stretching over the hill tops for several miles.

The questions having reference to unbroken sequence in this section are, first,—is there a fault between the dolomite and the next band of quartzite? and, secondly,—is there one between that quartzite and the Logan rock to the north of it? I do not hesitate a moment in saying that there is no fault at the first of these points. In so pronouncing, I endeavour not to be influenced by the evidence of the last section, because neither can the dolomite nor the quartzite be traced into connection with the masses there seen;—I judge merely from the appearances of the ground.

The dip of the two rocks is the same—about 20°; the cliff-faces of the two are parallel; the sward lies perfectly smooth between; and there are no appearances of faulting along the strike, in either direction. As to the second point,—as the distance is much greater, and the surface heather-clad and rough, there is no evidence either way,—there is certainly no evidence of a fault; but, seeing that, on the other hand, the Logan rock can be walked along continuously to where it overlies limestone in the last section, this is assuredly admissible evidence against the existence of a fault.

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While, however, this section does not perhaps offer any more direct evidence against the existence of a fault (that is of the Logan rock being merely the Hebridean) than did the last, yet it negatives still more decisively the theory of an inversion. For,—even supposing that the non-appearance in inverted order of the beds of dolomite and also of the yellow beds be disregarded; and that the one band of argillaceous and cherty quartzite be allowed to represent the hundreds of feet of that rock which lie a gunshot distant to the south-west,—what mode of inversion of the fundamental gneiss could fold the quartzite over the dolomite, so as to be beneath a mass of that gneiss itself, and at the same time carry that quartzite upon its own upper surface in such a manner that the said quartzite formed an overlap to a local basin of conglomerate,—a basin of a nature which has never been found in, or connected with, the *lower* quartzite at any locality whatever?

The section near to the western opening of the Bealloch of Braebag—Tharsuin falls next to be noticed. Standing at the bottom of the pass, and looking north-eastward, the long rugged sweep of the craggy face of Coneveall stretches before us from west-north-west to east-south-east. We are looking at the strike-joints of the rocks. Immediately in front, there is a pinkish flinty quartzite, dipping into the hill face; this is overlaid by very thin argillaceous beds, and then by a scanty fringe of wasted dolomite; these are conformable. Surmounting these, we find a narrow terrace formed of comminuted fragments swept by torrents from the cliffs. Lying upon this terrace there are isolated blocks of quartzite, with adherent albitic—porphyry, Logan rock, a green schistose rock which is sometimes adherent to the Logan rock, and great masses of the conglomerate. This terrace of *débris* of course prevents all confident assertion that the rock next seen overlies the lime, seeing that the *débris* may conceal a fault.

The foot of the cliff is quartzite of ordinary appearance,—this is disposed in thick beds up to about half of the height of the slope. Here there is a junction, at an angle apparently of 35° or 40,° *along the strike*. Were this appearance considered *per se*, the question might be put, is this a diagonal fault with an overslide;—is it the line of an overlap;—or does it represent the marginal edges of a lenticular mass of rock?

Though it is a matter of no difficulty to scale the face of the hill at several points, it is difficult, from the looseness of the rocks and the frequent shooting of stones, to keep a course along the junction; and at the most critical point this cannot be done.

Looking from below, it will be seen that each bed of quartzite suddenly thins as it approaches the junction, and has an appearance of passing as a mere filament under the Logan rock. Looking at the Logan rock, at no spot visible from below can it be seen to touch the quartzite. A verdigris-green fissile bed, which is apparently thicker towards the bottom, intervenes. It is also evident that the Logan rock itself thickens eastwards in a bedded manner, if not in actual beds.

Examination at the junction shows that the foliated green bed is very different from any yet described; it is composed largely of a lustrous flat-bedded but slightly wrinkled material, which has more the appearance of a green mica than of chlorite. No attempt was made to analyse it, as it was manifestly very impure; containing imbedded sharp-angled granules of quartz and of felspar, so as sometimes to have an appearance approaching to a micaceous *grauwacke*.

This bed is one of great importance. When the rock *in situ* is broken into, it is seen that the verdigris tint is external. Internally it is indistinguishable both in colour and structure from the fissile bed seen beneath the Logan rock, both at Glen Logan and Glen Coul.

Now it has to be asked,—what are we to make of this bed, on the theory of an inversion of the Hebridean?

If the Logan rock is to be regarded as a member of an ascending series this is a clearly individualised member of such series. What is it if the Logan rock be but the Hebridean inverted? For such a bed occurs nowhere in the Hebridean where it is *admittedly* beneath the Torridon conglomerates.

At the junction, any draw or drag which can be spoken to is downwards; *i.e.* south-eastwards. This negatives the idea of an overslide. The whole appearance is that of a falling shift to the south-east.

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The chief interest in this section lies in the question whether the upper bed of quartzite (which as a line of cliffs forms a cornice to the hill), overlies the Logan rock of the east, and the quartzite of the west of the escarpment, *without break*. For if it be contended that the terrace of débris conceals an east and west fault, and that the west end of the hill is lower quartzite, then must the two quartzites —the lower and the upper—*come together* in the western slope of the hill, unless dolomite or Logan rock intervene.

The only direct evidence which the writer is able to submit, bearing on this is, that at no point which he could reach or see was there any appearance of yellow beds or of dolomite; that the green schistose rock and the "Logan" seemed to disappear by thinning off at about a central point in the cliff face; that the upper grit extended somewhat further west than that point, but also thinned off; and that he could nowhere see the conglomerate in the west end of the cliffs.

As bearing, perhaps, upon this question, it falls to be noted, that upon the western slope of Coneveall, and not far to the west of the point where the Logan rock with the fissile green bed and the conglomerate would, if continued westward, crop out (if not overlapped by the upper quartzite), there are found two beds of a much-rotted foliated rock of a green colour, with a medial bed of a pale felspathic grit; and below this there is a similar bed so weathered as to show only a foliated green mineral, impacted in minute crystals in a soft kaolinic material.

The grit is similar to that under the conglomerate, while the altitude is about the same. The rotten rock is in structure similar to the "Logan," where seen near the Whitten Head intercolated with quartzite. Possibly these beds may represent the fringes of the fissile bed of the "Logan," and of the conglomerate; while some may consider that greater probability attaches to the view that they represent what Nicol terms "wayboards," or belts of decomposed igneous rock. These "wayboards" will be considered in the sequel. I have found the same slimy fissile rock in a similar state of decay, and weathering into a plastic clay, at spots on the ridge leading to Ben More proper; and also some distance over its north-eastern slope. I have never seen it in the lower quartzite.

My reading of this section is, that though there probably is fracturing in the Bealloch of Coneveall from the swinging of the whole system of rocks round the basin of Loch Maoloch Corry, there is no faulted upheaval north of the dolomite; that the great cliffs of the west of the hill are upper quartzite, and that we are here at the marginal fringe of a great incoming lenticular mass of Logan rock. To this conclusion I am guided by the incoming on the opposite slope of Ben Harran (apparently continuous with those of Coneveall) of many beds of the albitic porphyry, which is known only in the upper quartzite. I regard this, however, as a most perplexing locality; it is one, moreover, upon which the theories of fault and of inversion can only be brought to bear, at the cost of "making confusion worse confounded."

We now pass to three sections which are seen in the Glen-Coul district.

The more southerly of these starts from the road to Unapol, at the foot of Cnoc Coir a Bhaic. Quartzite here lies nearly conformably upon what will afterwards be shown to be the *lower beds* of the Cambrian conglomerate. This quartzite, dipping gently to east-south-east, forms the whole height of the Cnoc, and extends a short space eastward of the shore of the tarn of the same name. Quartzite-shivers and heather prevent our determining whether any dolomite here occurs, the first incoming rock being the "Logan," which ascends into the rough-surfaced Cnoc na Craige. From this it sweeps eastward across Coire Ghuirm till it is seen to be either overlain or to abut upon sheets of quartzite which sweep down from the north side of Ben Uidh. The junction at this spot I have not visited; the appearance from the summit of the Cnoc, and all along to the summit of Glasven, is that of an overlie.

Northward, the Logan rock sweeps by the Leitir-Dhubh, across the trench of Loch Beag, in under the quartzite foot of the upper gneiss in the Stack of Glen Coul. Southward, it forms the whole ground from the east shores of Loch na Gainmhich, to within a few hundred feet of the summit of Glasven. Logan rock is again met with about two hundred feet below the summit on its south side, whence it extends southward to the burn of Chalda.

As the connections of the Logan rock with the quartzite are for the most part

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obscure along this line, the chief interest relates to bands of a dark muddy-green dense aphanitic rock which repeatedly intersect it.

Two bands of this are seen in it, but a short distance from its junction with the quartzite at Loch Coir a Bhaic; these bands cross it with very much the appearance of dykes, but exactly in the line of the outcrop of the rock; and there appears to be a rude bedding of the Logan rock conformable to these bands.

In the north spur of Glasven, which lies between Lochan a Choire Dheirg and Lochan a Choire Ghuirin, other three veins or beds of the same rock appear,—the first of great thickness. The junction of the Logan rock with the quartzite which succeeds, is concealed by splinters of a vitrified-looking red quartzite. What is seen leaves some impression of a fault. A double syncline and anticline of quartzite succeed; the descending fold of the latter being, on the south side of the hill, regularly overlain by Logan rock, with an apparently-conformable bedding, in which bedding two other bands of the dark rock are seen, as regularly disposed bands. In descending the south spur of the hill, there is an upthrow fault which brings the quartzite into view. A small cliff of this, thirty to fifty feet in height, can be walked along for many hundred yards, the Logan rock *forming a thin overlying cake for the whole distance.* This cake extends to the burn of Chalda, in the bed of which it either abuts against, or is faulted on to the quartzite hemidome of Cnoc-an-drien. Two dykes of indubitable igneous rock are seen a little way above the Chalda burn. They consist of dark augite with magnetite and labradorite (?),* the latter being sometimes in groups of radiating crystals. The north-east fringe of this overlying cake of "Logan" is seen but a little way over that slope of the hill, where it is seen that the cake has but little thickness.

While it is almost inconceivable that so thin a band as that here seen, dipping at so low an angle—about 28°,—can represent the Hebridean gneiss, still the interest here lies in the so-called aphanitic rock, as nothing macroscopically resembling it has been seen in the lower gneiss. In addition to the characters already noted, the lens discloses nothing except that it is riddled to a great extent by excessively thin veins of epidosite (?); it shows an obscure foliation, which I also observed to accord with its bedding surface.

The microscope, however, reveals that its structure is of a highly characteristic nature, being delicately schistose, and with its foliations corrugated in a beautifully rippled manner. It consists of myriad layers of minute crystals of hornblende of a very uniform size, and a form like grains of rice; these are impacted, apparently with the axes of the crystals all pointing in one direction, in clear viscous-looking quartz. They lie in single file forming each layer of the rock, and thrown into undulations generally where they are interrupted by the venation of epidosite. The quartz is devoid of fluid-cavities, and also of inclusions.

The occurrence of repeated bands of such a rock in so large an amount, here and elsewhere in the "Logan," apparently conformable to the underlying rock, taken in connection with its non-appearance in the Hebridean rock, cannot but be received as evidence against the identity of these rocks.

Section at Liath Bhad.—This section may be taken from a little bay on the south shore of Loch Glen Coul, where the Hebridean gneiss is seen in well-marked beds dipping gently to the west-north-west. Here the quartzite, dipping about 10° in the opposite direction, immediately overlies it,—as the Torridon does not descend the hill slope many feet from the foot of Cnoc Coir-a-Bhaic. Ascending the opposing slope of Liath Bhad, we find that the quartzite is here feebly developed, as we soon come upon the argillaceous beds. These are here in force, forming an encircling line of cliffs of 60 to 80 feet in height, the beds of which dip at about 20°. Surmounting these, and ascending to the foot of a beetling cornice of rock, we arrive at one of the best disclosed sections in the district. This is laid bare by a fall of rock, so that what is seen is unmistakeably seen. The dolomite is struck at its western fringe.

A well-defined bed of calcareous chert, containing nodular masses of crystalline dolomite and passing into a bed of dolomite itself, passes immediately under a bed of a very fissile chloritic rock of about six feet in thickness. The dip is 26° to 28°. Here and there a few inches of a cherty rock, undistinguishable from that described

* The same igneous rock cuts "Logan" on the north side of Conveall.

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at the Dhu Loch More section, intervene. The chloritic rock here seen is identical in appearance with that seen in a similar position in Glen Logan, and it differs from that spoken of in describing the last section only in an appearance of greater looseness of structure, apparently due to incipient decomposition. Over the schist there is a beetling mass of rock which has an unctuous feeling. This cuts with a knife, somewhat resembles agalmatolite, and is identical with that seen at the bridge over the Loin river.

To this last, ordinary "Logan" succeeds; but, as the cliff face cannot here be scaled, I cannot say if the "aphanitic" rock occurs in this part of Cnoc-na-Creige.

Where the cliffs of the Liath Bhad descend into the water, opposite Eilean-an-Tuim, the section, which is beautifully disclosed, reads,—white worm-hole quartzite; red ditto, thick; fucoid bed; yellow beds, thick; blue belt; gritty bed; yellow bed; dolomite; cherty bed, thin; green schistose bed; massive "Logan;" red "Logan," like Cnoc-na-Strome rock.

Stack of Glen Coul Section.—On account of the presence of the Loch, the west end of this section must be taken along its north shore,—the Aird-da-Loch.

Of this the west end, for about a mile and to a height of about 550 feet, consists of Hebridean gneiss. There is no Torridon rock—a cliff of pinkish flinty quartzite immediately overlying the first rock. A second much wasted white band of the same rock succeeds; and upon this, at an elevation of about 680 feet, there is a small outlier of the Logan rock, standing a considerable distance from the main eastern mass of that rock.

There are here neither yellow beds nor dolomite. The quartzite dips at such an angle as to come down to the water edge, about one and a quarter mile further up the loch; and above this spot the yellow beds first come in, and then the dolomite a quarter mile still further east. There is thus a distinct overlap. A stone thrown by a powerful arm from the outlier, might alight upon the Hebridean rock on the shore of the lake. Faulting, with an overslide of a mile and a quarter at so low an angle, is hardly credible; and as there is no re-duplication of either quartzite, yellow beds, or dolomite, inversion is untenable in even a greater degree.

That there may be some crushing along the strike, is however very probable, as the yellow beds are seen to be tilted to an angle of about 82° in the islets at the narrows. The junction of the Logan rock with the dolomite at this point has been altogether obscured by cultivation. The former rock rises in the buttress-like foot of the Stack to a height of about 430 feet, when overlying quartzite is reached. This is, however, only a small outlier, for the ground falls to the east, and the connecting ridge is again "Logan." The beds of the quartzite outlier have a gentle dip to the east-south-east, and are perched on the very centre of the Logan ridge. Looking eastward to the continuation of the ridge, however, there is seen to be a certain amount of unconformity between the "Logan" and the overlying quartzite *along the strike.*

The core of the ridge, and its northern slopes are "Logan;" and it is overlain at its summit by many beds of quartzite, which are nearly horizontal along the strike; but a great part of the south side of the ridge is composed of beds of quartzite which are inferior to those which pass over the summit of the ridge, and which thus abut (at an angle of about 50°) against the sloping side of the Logan ridge.

The impression conveyed is that there had been great denudation of the "Logan" before the deposition of the quartzite. There is no fault,—as the upper beds of the quartzite pass unbroken over inferior quartzite, and "Logan rock alike." There is a lenticular thickening of the quartzite along the strike.

The junction here is a most instructive one, as there is a well-marked passage bed, of about four feet in thickness, between the "Logan" and the quartzite. This bed, much the same colour as that of the "Logan" itself, is formed of its substance in a more or less finely comminuted state, mixed with quartz grains, and distinctly laminated conformably to the overlying beds of quartzite.

This quartzite itself is altogether different from the quartzite seen below the yellow beds at the hill foot. It is finer in grain, with more cement, entirely free from worm-holes, and at distances in its thickness which vary from four inches to a foot, it displays bands which have suffered atmospheric disintegration. These bands are little over an inch in thickness, and they are frequently, through rotting, de-

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pressed to an equal distance below the general surface of the rock. They show a laminated structure which is partly due to enduring mica. When the rock is broken, however, they are visible only near its surface, and that through a comparative looseness of structure and the presence of an ochrey powder. Mr. Hudleston was of opinion that these constitute the "way boards" of Nicol. I have never seen this appearance in *admitted* lower quartzite. It is just when the brow of the ridge is surmounted, and the true foot of the Stack is reached, that the junction of this quartzite with the upper gneiss is seen.

Writing of this spot, Mr. Hudleston remarks—"There really seems to be a sort of lithological passage between the regular quartzite and the fine quartzose flags which gradually conduct to the more micaceous beds."

It was shown below that the quartzite had changed in appearance so as to be far from "regular quartzite;" but as if to give force to this linking transition, the quartzite again becomes "regular quartzite," just after the cliff is surmounted; for its beds are here white, distinctly granular, and full of worm-holes.

The mode of the transition into the quartzose flags varies at different points. A little south of the nose of the Stack I found a worm-hole bed overlain by a very fissile somewhat green bed, then a second worm-hole bed, and then fissile horny flags, splendent from innumerable layers of greenish mica.

Directly south of the Stack there are worm-hole beds overlain by open-grained fissile beds, of which mica is at one and the same time the agglutinant and the laminating material. These beds contain worm-holes, which are generally somewhat flattened in the direction of the lamination of the mica. Take away the worm-holes, these would be called upper flags. With the worm-holes, what are they? It will be interesting to study the chemical side of the theory which is to show how either faulting or inversion can make mica!

The micaceous beds to which the flags "conduct" are seen, unmistakeable in character, on the summit and neck of the Stack. The mica is so green and the structure so plicated that it might be set down as chlorite slate, were it not for the splendent lustre, and the durability of the loosened scales. These sparkle in every pool, or rustle as they are swept by every puff of wind.

The localities and sections above cited are probably sufficient to enable an opinion to be formed as to the nature and age of the Logan rock; but here I must say with Mr. Hudleston, "it may well happen that in the long range from Whitten Head to the Sound of Sleat, more than one class of rock has been enumerated under this head." I do not for a moment regard it as even unlikely that the Old Gneiss has been thrust up at some points; and I would much like to re-examine a great wedge which is seen north of Ben Uidh,—evidently faulted. Speaking of the rock or rocks at the described localities, those seemingly overlying the dolomite more or less immediately, and those seemingly interbedded in quartzite,—and, admitting many difficulties and occasional obscurity,—I may be allowed to say that, *while the sections seen in Ross-shire are simpler and clearer, the foregoing facts alone seem to me to indicate that the Logan rock is a grit which presents varying degrees of metamorphism up to a perfected gneissic structure;—a grit formed out of the Hebridean gneiss, occurring in great quantity where the removal of the cover of Torridon rock exposed the Hebridean to extensive denudation, and hardly seen at all in those districts where that cover had shielded and still shields it.*

Those who hold it to be the Hebridean gneiss may be directed to An Criochan,—three miles south of the Whitten Head,—where two beds of "Logan" three feet in thickness, will be seen in the middle of a quartzite cliff.

The Gold of the Drift.

At the time that the "diggings" were being carried on, and that the country was being searched in all directions by hundreds of "vagrom men," Dr. Joass was taking notes of all, and he also engaged in personal exploitation. What follows is for the most part a condensation from his elaborate observations, as communicated to the writer.

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The extent of country over which gold has been ascertained to occur is about 20 miles from north to south and 30 in width. The rocks are gneissose schists and igneous rocks, whose courses conform to the strike of the sedimentary rocks.

The igneous rocks are (*a*) a large-grained porphyritic granite, which stretches along the south-east of the district, and (*b*) a red small-grained granite, which conforms to the strike of the gneissose rocks, and which sends out across the strata, as if into transverse fissures, short dykes from which small veins insert themselves between the more micaceous beds. In the most richly auriferous localities granitoid rocks (*c*), chiefly felspathic, are so intimately connected by interlamination with the flaggy quartzose strata that they almost appear to be the result of metamorphosed action upon true sedimentary rocks. They may, however, be contemporaneous effusions of plutonic rock.

"I venture to think that the coarse-grained porphyritic granite of the Ord and the south-east of the district should be regarded as truly plutonic and associated with upheaval. Throughout the auriferous district the red granite appears to be an intrusive rock, conforming in its course to the strike of previously elevated strata.

"The binary compound of quartz and felspar termed granitoid suggests a metamorphosed gneissic rock whose particles, yielding to such agents as heat and electricity, were melted and mineralised *in situ*. It does not appear inconsistent with this opinion that the rock in question, which is as thinly bedded as the flaggy sedimentary strata with which it alternates, should occur as a short transverse dyke, as it seems to do at Suisgill.

"If we suppose that fissures caused by local upheaval were contemporaneous with metamorphic action, these fissures would be filled by a molten rock, whether its materials were supplied on the spot or intruded from beneath." (Always supposing that there be no surface orifice of escape.)

There is also a wall of whitish hard and brittle quartz rock, which forms the Scarabin Hills. This suggested to Sir R. Murchison the idea that it was "the result of intense metamorphosis of lower Silurian rocks."

Gold Localities.

Strath Brora.—The Blackwater, in small scales from the drift lying over micaceous schist with interbedded granite (*b*), but none in burns which enter it after a course over Old Red Sandstone.

The Crask.—A small quantity at the head of the Clyne-Milton burn, over flaggy quartzite. None in Kintradwell Burn—flaggy gneiss; nor in Allt Choille—Oolitic sandstone.

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Glen Loth.—The Loth-beg water, over porphyritic granite (*a*) none. Culgower burn, granite; none. Kildonan burn, over Old Red rocks, none. Craggie burn, gneissose rocks; auriferous.

Strath Ullie.—Helmsdale river, flaggy micaceous and gneissose beds traversed by granite (*b*), very rich washing, in river side pockets above Crask bridge. Kildonan burn, quartzose and gneissose, with quartz veins encased in chloritic clay, felspathic rock (*c*) present in small amount, drift of local origin, generally a ferruginous gravel. Above this is yellow clay, overlain with coarse sand, containing flexed dark earthy lines in section; the whole is covered with thin peat moss.

Gold found in greatest quantity in the lowest portion of the alluvium, but occasionally from the wash dirt immediately under the turf.

Suisgill.—Flaggy gneissose rocks with an abundance of felspathic rock (*c*) interbedded with the strata. The more friable felspathic varieties of this rock are readily disintegrated, forming sometimes a white plastic clay, sometimes a gritty sand. Towards the head of the stream this and other large-grained friable granitiform rocks become abundant, forming great slopes of granular grit. Much gold in pellicles of larger size than elsewhere.

Allt an t'Fhionnaraidh, same rock, a half-inch water-rolled pellet contained gold mixed with felspar and quartz. This suggested the binary granitiform layers and grits of the upper Suisgill. Knoc Fhinn River, branch of River Fri, gneissic flags, with much large-grained intercalated granite: a little gold. Allt Ceann á Phris, red granitiform rocks with flaggy beds; a small nugget, 5 dwts., and a good deal of granular gold. Alltduible, Allt-bhreach, and Allt-torrish, gneissic rocks, but approaching the granite (*a*); not richly auriferous. Kil-Pheadar and Cairn burns over granite (*a*); no gold.

Sgerreabeim Range, quartzite; no gold.

Elsewhere I have received notes as follows:—

In two burns between Ben Smersal and Gordonbush; in Auldtown burn. In the Helmsdale water below the bridge at the village, and on the river bank behind Mackay's Inn, shotty gold with iron sand. At Kilcormkill, six miles from Brora, in a tributary of the Brora river.

Such are the localities in which gold has been found, loose lying.

Whence came it?

Sir R. Murchison says, "transported from the great central plateaux of Sutherland." Mr. John Campbell, of Islay, is more precise, as he fixes upon Klibrick, or thereabout.

Dr. Joass says, "Nearly every stream within the area here described

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has been well searched by practical diggers, *and the fact that many of them, as already mentioned, have been searched in vain, suggests no wide-spread deposit, the result of extensive glaciation, but several independent centres connected with the local rocks.*"

This last conclusion must be held to be the correct one. Any agent of transport which conveyed particles of a material specifically so much heavier than the ordinary drift as is gold, must have left the greatest amount of these in the nearer cross-courses, and could not have carried them to the more distant, to deposit them in these also in an anomalously selective manner.

Gold has not, moreover, been found in the westerly cross-course pockets and ravine traps; and it could not fail to be difficult to explain how it was swept over these to be lodged most abundantly in the beds of streams, the channels of which, though each of the nature of a *cul de sac*, yet lay open to the easterly sweep of the drift.

But the records of Dr. Joass's chronicle give information more definite than this. Not in the streams which drain from the quartzite, or sweep over the granite, or cut trenches in the Old Red grits, but *only in those of the gneissose rocks.*

Dr. Joass writes, "Several specimens of water-rolled stone, rich in gold, have been found in Suisgill and Kildonan burns; in every instance the components of these stones are felspar and quartz, with one exception, in which there is quartz only. Arguing from the comparative poverty of the drift, where this rock or its detritus is scarce, and connecting its prevalence in Suisgill and Kildonan with the rich alluvium there, we may venture to infer that the granitiform rock is the matrix of the gold."

In this, however, the writer is hardly disposed to go altogether along with Dr. Joass. In speaking of the so-called syenite of Loyal and of Lairg, he had occasion to speak of the very small amount of hornblende which was present in these rocks. He had the advantage of being taken over part of the auriferous district by Dr. Joass, and, from what he saw of the "granitiform rock," he was not disposed to regard it as metamorphic, but intrusive. Still it did seem to him, at Suisgill especially, a rock very similar to that of Lairg, only deficient—that is still more deficient—in the hornblende. Coarser grained, and more of a granular and less crystalline structure, but with the same facies.

Though in many parts of Aberdeenshire he has seen what he believed to be a metamorphic granite, which had been formed by a change which had affected all the zoned bands of a convoluted or unconvoluted gneiss alike, still the change had in all cases affected *the whole mass of these alike*,

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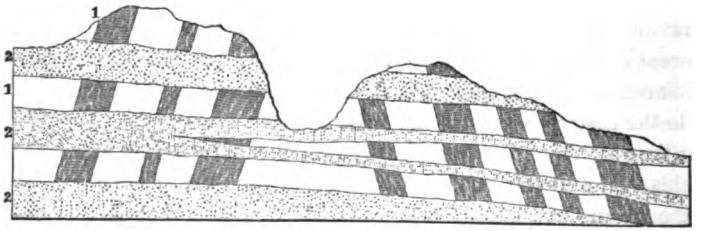
up to the line or zone where the unaltered gneiss appeared. Here, however, as Dr. Joass has shown, nearly parallel and even bifurcating bands of this rock cut horizontally across the "deposit layers" of a laminated gneiss, which has an anticlinal dip. The appearance being like the stroke which would convert an inverted V into an A, or rather a series of As of different sizes packed within each other, the intermediate spaces of the laminated rock being left quite unaltered.

As this is a most singular rock, a copy of Dr. Joass's illustration is given.

Granitiform rock in decomposed Gneiss, Suisgill.



1. Decomposed gneissose rocks dipping S.S.W. and E.S.E.
2. Granitoid rock (*c*).

All writers who have speculated upon metamorphism have called in the aid of heat; some bring it from below, some from above. The writer goes a step further, and, with Daubrée, believes that an augmentation—which may be the turning point of the changes—may come *from within*. However, so we do get it, we are glad to get it *anywhere*. But under none of these suppositions can it be understood how there should result a *zoned action*—a band of concentrated energy, with a superimposed inert layer; alternately superimposed, moreover, above each other in repeated sequence.

Certainly, if it were an *untilted* rock with alternate highly felspathic, quartzose, and micaceous layers, such a result—that is, such a banded structure—must follow upon metamorphism. The felspar would yield the zones at once. Nay more, the rock as a whole might settle down into a granitic paste. But what is called for here is very different.

It certainly is a striking fact that there is no trace of dislocation in any part of the traversed layers of the schistose rock. This is almost demanded upon the supposition of intrusion from any direction, of a rock whose layers lie at such varying angles; while, on the other hand, it is as imperatively demanded (upon a supposition of metamorphic change) that the layers adjacent to the metamorphosed bands should have been loosened in

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structure—opened out, deflected in some part, where they were softening into the granular magma.

Most interesting as it is in relation to metamorphism, the bearing of this rock on the present question is whether or not an igneous rock, or a rock which has undergone metamorphic change, can be the probable matrix of gold, while the non-metamorphosed rock either does not contain it or at least yields it in a less easily *apprehended* state. For it is quite possible that during the metamorphic process like might draw like together, so as to cohere in more palpable lumps. But with such knowledge as we have of the rock-matrices of gold elsewhere, we must hesitate to credit granite with being its matrix.

While, however, it was most convenient for Dr. Joass to assign his quartz-felspar nodules to the granular grit of his granitiform rock, I have to say that in all the specimens I examined, both the quartz and felspar of these nodules appeared to me to have more the appearance of being those of an exfiltration vein. While disposed, however, to believe that the occurrence of such veins in the rock is sufficient to account for such specimens, I am inclined, from what I saw of one quartz vein, though of only that single one in Kildonan, to believe that the larger quantity of the "scale gold" came from such purely quartzose veins.

The evidence yielded at the time by the vein referred to was not very direct. The writer broke off a large and, as he thought, a clean mass from the vein, carried it some eighteen feet above the stream, and broke it carefully up, using a cleaned rock as an anvil. In his search among the gradually removed fragments he found no speck, but he had hardly left the spot when he was recalled by Dr. Joass, who pointed to a speck of gold lying among the powdered quartz. This speck the writer does not think could have come out of the quartz, *unless it was from an open cavity*. It had none of the hackley structure of attached and imbedded gold, nor had it its superficially dull colour. It was smooth and brilliant, *rubbed* in fact, and so must have been merely either lodged in a chink or attached to some mud upon the rough sides of the quartz.

Notwithstanding this failure as regards the only "likely vein" which the writer saw, he considered it to be so likely a one that he has little doubt of its being more or less auriferous. He also does not hesitate in joining issue with Dr. Joass in regarding the Sutherland gold as being of *home growth*, and *not far carried*.

The quantity of hepatic pyrites found in the washings seems to have been very small, as also of "*keely*" or "*keels*."

Black magnetic iron sand also was in so small quantity that no sample

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could be had for analysis, though it was of considerable moment to determine whether it was magnetite, or iserine, or crushed ilmenite.

Black *rutiles*, of about the size of peas, were occasionally found. The figure of a complex twin which I saw in Mr. Heathfield's hands is given. Minute dodecahedral *garnets*, scales of *mica*, and *specular iron* are also found.

The larger pieces of gold which I have seen quite bear out the view that they have not been carried far; they are mostly in the form of thin scales with remarkably rough sides. The colour is pale, with a slight tinge of green.

The following are analyses. That made by myself was executed upon scales, of the size of the nail of the little finger, purchased from Mr. Wilson, of Inverness.

	S. G.	Gold.	Silver.	Iron.	Silica.
1. Suisgill	15·799	81·11	18·45	—	0·14= 99·7
2. Do.	—	81·27	18·47	—	0·26=100·0
3. Kildonan	15·612	80·34	19·86	0·12	tr=100·32
4. "Sutherland"		79·22	20·78	—	=100·0

1. David Forbes, *Phil. Mag.*, Vol. XXXVII. 2. Ditto. 3. Heddle. 4. Makins.

The figure is that of the largest nugget found: it was from Suisgill. This is now in the possession of His Grace the Duke of Sutherland: it weighs 2 oz. 17 grains.

Since the above was written I have been instructed by His Grace the Duke of Sutherland to analyse a quartz vein which occurs in the Suisgill Burn. This vein was examined in consequence of statements having been made by interested parties that the rocks of the district contain large amounts of both silver and gold. The crushed quartz was examined by the most perfect amalgamation processes, and yielded a button in the proportion of 89·2 grains per ton. This button, upon analysis, was found to contain—

Gold	... 28·57
Silver	... 71·43

being in the proportions of a very poor *electrum*.

This quartz vein yielded small quantities of *ilmenite* and *magnetite*, and it also yielded so considerable a quantity of magnetic iron, which precipitated copper, and was bruised by the friction of a pestle, that I communicated with Messrs. Johnson and Matthey (who had crushed the quartz) as to the possibility of its having been abraded from the stamps. The following reply was received :—

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"Nov. 16, 1880.

"DEAR SIR,—In answer to your letter of yesterday, we beg to say that the sample of mineral sent to you was crushed on a cast iron roller mill. We do not, however, think that any particles of iron became mixed with the ore during the process of crushing.

"Yours faithfully,

"JOHNSON, MATTHEY & Co."

I accordingly examined the iron, so far as the quantitative determination of silica and carbon. Of the former there was 12·1 p. c.; of the latter ·79. This being a proportion of carbon very much smaller than any cast iron contains, it at least becomes a question if some *native iron* be not present in the rock, sheathed, like that of Unst, in magnetite.

Old Red Sandstone.

The first westerly appearance of this formation is where it reposes upon rounded bosses of gneiss in the neighbourhood of Tongue.

Here it forms a north and south line of disconnected outliers of a conglomerate, very different in appearance from the conglomerates of the west.

Hugh Miller cannot have noted these differences, as, in his whimsical comparison of Sutherland to a gneissic picture set in a sandstone frame, he made use of some part of these northern outliers to form the top rail of his frame.

Nicol also seems to have correlated them with the western conglomerates, for he says that if they belonged to the Old Red formation, we should find some fragments of limestone. These, in fact, do occur in such abundance in a small outlier—which exists at sea level south of the Harbour of Scullamie—that calcareous sinter incrusts the face of the rock.

The character of the conglomerate of the Tongue outliers is altogether different from that of the Torridon rock.

It is formed of masses which are of much larger average dimensions, while they are much more brecciated and less generally rounded. Upon closer inspection it will be observed that the component masses themselves, in general, belong to much less crystalline rocks, while the rock itself looks of far less age, probably from a greater looseness of structure, which appears to be due to a deficiency of cement.

In the hills round Tongue the bedding of the rock is not well marked, and there are but few beds of a fine grain. Further north, however, as in the cliffs of Craig Vercan and Roan Island, the bedding is well marked

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and even in the latter free; while in the hollow which lies immediately east of Ben Breck a purplish red sandstone hardly distinguishable from the rock on the summit of Teallich is found.

The lower beds of the outliers called the Griams are formed of a rough, angular, and occasionally granitic conglomerate, which passes into upper beds with more highly attrited components.

It is upon the authority of Mr. Crawford, of Tongue House, that I have placed conglomerate upon the summit of the Craig Mohr of Ben Armine. It certainly hangs on to the north skirts of Stomino, and caps some of its elevations; and Mr. Crawford holds that the Ben Armine outlier connects this with the masses in the neighbourhood of Loch Brora.

I have neither seen nor heard of any mineral body in this conglomerate beyond the occurrence of patches of reddle in the sandstone east of Tongue; an occurrence which is one point of distinction between this and the western conglomerates; no fissile schist which could weather into reddle occurring in the Hebridean rock. Other parts of this Tongue rock more resemble the purple flags near Braemore.

Reference has before been made* to the three varieties of conglomerate at Portskerry, Red Point, and Isauld Burn mouth, and the opinion of Sedgwick and Murchison that these could not be correlated with one another has been considered.

There are certainly marked differences between these three varieties of the rock: the first containing sharp-angled and pale-tinted greenish fragments, imbedded in much granular, felspathic, and sandy paste; the second has little paste,—this is granitic in character, while the imbedded masses are rough surfaced, nodular, and highly felspathic; while the last consists of much rounded and smoothed balls of syenite which are impacted loosely in a firm cement of the same description.

There can be no question, however, that these are mere local shore lines, and that the varying features are due to the varying characters of the parent rock from which the fragments were torn.

Admirable lessons are—especially at the two last localities—taught as to the formation of conglomerates. Precisely as in wandering round the shores of a sandy bay, we at the present time find a rolled and rounded shingle overlying a bed of sand at one spot, and mantled by it gradually at another, while on the opposite shore splintered and angular slabs which have slipped from some overhanging cliff are covered up here or washed bare there of the gravel swept seawards by a stream, so do we

* See pp. 241, 242.

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read in these rocks the arrest of these processes of chance arrangement, and have evidence of the fluctuating circumstances which are ever associated with the zone where wind and water meet.

There is probably no locality in the country where this is better illustrated than at the Red Point. Here an old shore line drawn in zones of granitic shingle and enveloping silt, and elevated some 50 feet above the present water level, has been so air wasted and wave-washed that the rougher masses of the shingle protrude through the blue flags precisely as do boulders and coarse shingle above the sand or slime of a recent beach.

Speculations as to the cause of the fracturing seen here, and which has been adverted to both by Sedgwick and Murchison and by Geikie, can hardly be entered upon without leading to a consideration of the circumstances under which the formation as a whole was laid down. For it is certainly a circumstance worthy of note that while mile-long stretches of the shore exposure of the formation show vast sheets of rock continuous without break or even flexure, those points where a local base presents itself, or where we are approaching to the true base of the formation as a whole, should evidence dislocation, smashing, and repeated elevation or downthrow.

It is not to be wondered at that in such circumstances local effects should be referred to local causes, and that where a granitic rock was present it should unhesitatingly be regarded as the source of the disturbance. Those, moreover, who adopt such a contention must at least be allowed to claim that, before their views are discarded, some indication of a more feasible cause should be at least indicated.

If we can as yet do little more than this, we can at least show how, under more consistently developed views of the circumstances under which formations circumscribed in extent were formed, there is good hope for the belief that the explanation desired is almost, if not altogether, within our reach.

For the old view, that the successive deposition of sedimentary strata on a limited space of the earth's surface was *an effect* of continuous depression of the sustaining surface, is giving place to that which regards it as *the cause;* while the belief that a *general depression* of the district had taken place at the time, and was all that had to be considered, must to an equal extent give place to the view that the depression and formation of the trough by the accumulating weight of the sediments could only go on *pari passu* with an equivalent elevation of those tracts of country

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which (lightened of their superficial beds, which as *debris* had been transported), were being thrust aloft to restore the equilibrium.

Old and new theory alike require at least a plastic substratum upon which the crust which is being flexured is to rest; but while the older view provided no receptacle or retiring ground for the displaced material of that substratum, this may be said to be not only amply provided for in the billow-like upheaval, but to be the immediate agent of the upthrust.

It is all too soon for us to attempt to estimate our indebtedness to those who first perceived that which now appears so evident,* or to those† who, following out the sequence of necessary results, showed how the counterpoising elevation, thrust aloft until its mantle of congealed vapour, by shielding the rocks from the more rapid agents of degradation, first stopped the supplies which were forming belt after belt below, thus bringing the first stage of the process to a close,—and then, itself overburdened by the ever-increasing weight of snow and ice, was borne down to elevate that which had been depressed, but which was in turn destined again to rise, when its subsidence to a more temperate altitude dismantled it of the coat of congelation which was normal only to the greater elevation.

So does Dr. Rickets argue out the cause of the glacial period; but geologists have evidence enough to show that old formations had their glacial periods before recent rocks were laid down. If the sequence in the reasoning is sound at all, the sequence of events must have taken place not once, but often. Nature must have repeated herself in this as in other things.

But there is a circumstance connected, perhaps specially, with this formation, though not with this formation alone, which has not, so far as the writer is aware, been alluded to in connection with this hypothesis of equivalence in depression and elevation; and this circumstance appears to the writer to have not only a very direct bearing upon the contention of Dr. Rickets, but to fortify its probability. I allude to the fact of a great fault running along the edge of the formation at or near its shore line. Such a fault is seen close to the junction of the formation on the east side of Shetland; and a similar fault crosses Scotland from Stonehaven to its western shores. More imperfectly and less continuously are faults seen along or close to junction lines, from Whitten Head to Loch Kishorn.

Had there been merely general depression of the crust in a district where a cinctured lake-formation was being laid down, followed by general

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* Dr. Charles Rickets, Mr. Starkie Gardner, and the Rev. Osmond Fisher.

† Mr. T. F. Jameson and Dr. Rickets.

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restoration of level, it is very difficult to see how the rent should occur, not where there was the greatest accumulation of weight and the greatest bending, but where the fringe was thin and the pressure altogether trifling. But, if on one side of a line of junction there be bending downwards, while on the opposite side there be flexure upwards, *there* must be the greatest amount of strain, and *there* or thereabouts there must be a certain amount of thrust and a great amount of twist, at the time when, after the slowly effected alteration of circumstances, the weight of the upward-borne land inverts the flexure. Should the rent pass downward so as to reach the yielding substratum, and should it be fluid, some portion will pass upward to plug the opening;—as is the case along the great fault south of the Grampians. Should the rent, on the other hand, be within the fringe of that which is the land, the displaced wave of plastic or fluent matter may be poured out in a line of volcanic throats,—as along the seaboard of the Americas, and other seaboards. Here, as a consequence of the plastic wave having found exit, there can be no elevation of land behind. Or, if the rent takes place within the margin of the basin itself, during the period of its subsidence, we may have a similar line of *subaqueous* throats throwing out flows which are to become interbedded sheets; as along the east shore of the liassic formation of the Western Islands. Here again, and for a similar cause, there may be no elevation of the adjacent land.

To altogether different causes are we to assign the rents and hitches, simulating the effects of local protrusion of igneous matter which are to be seen at such localities as the Red Point. The disturbance at these frequently appears to be due to more causes than one. Murchison says that the strata cannot be traced into junction with the granite on the east, though he goes on to say that the strata there seems not much disturbed. But this is not so. The strata can be traced right up to and touching the granite, and they are not disturbed to the smallest extent. Bed after bed of the flags rise, layer after layer, up the vertical face of what seems to have been a sea precipice of the older rock. For a short distance within the margin of the flags there is a slight downward drag, and that is all the "confusion;" the great slabs of the formation lie like a wide pavement altogether unaffected below. But round at the Point itself the two formations are brought here and there, as Geikie says, "together along a vertical junction line, by a few small faults." Sometimes washed out "geos" show portions of the older rock hanging over the beds of the newer, which occasionally appear to prop an isolated pillar.

This had been a promontory of the shore of the old lake. Had its waves, which cut the promontory into a straight faced cliff, cut also deep

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"geos" and left isolated stacks to be buried in the accumulating shingle, even as they are doing all round the coast at the present day?

Some portion of the appearances in no respect differ from these. Still there are others. While Sedgwick's imbedded block is not now to be found, still there are appearances of after-motion and bending of the flags, seen at or near these local bases, and there alone. These promontories with their outstanding stacks, around and between which the conglomerates have mantled, are the rivets by which the one formation keeps a firm hold of the other.

This is admirably seen at Port Skerra, where aiguilles and spikes of the old rock penetrate the beds of the new like the fangs of a dog; bearing, however, a still greater resemblance to the manner in which the rocky spikes of a Highland hill pierce the under surface of a great sheet of snow, and keep it hanging on to a slope, despite its tendency to slide into the valley.

Some such drag there must have been here, when re-elevation pulled the still moist basin of the Old Red up to a level which was to become dry land. The dip is all away north-westward; and just as some portions of the conglomerate are at Eilan Roan even now slipping back into the waters, might there have been a tendency to slide here. But the roughness of the underlying rock prevented separation; the great stretch of the formation in front nearly altogether prevented crumpling; and at the promontories, as at Port Skerra, the old rock had got so firm a grip with its fangs, that although there may have been some small amount of tearing, the grasp was so sure that even yet the spikes and aiguilles hold on to some fragments which the sea has not been able entirely to carry away.

Of the upper members of this formation, as seen at the border-land near Reay, Geikie, in his classical essay on the Old Red Sandstone of Western Europe, has told all or nearly all that there is to tell. To the accuracy of his general description of the strata from Holborn Head to Strathy the writer can vouch. He has some doubts as to the correctness of his view, that the beds in the neighbourhood of Bighouse overlie those nearer the Red Point, nor can he admit that the grounds of his inference—for it is nothing more—are either sufficient or at all conclusive. Mr. Tait also, who is very familiar with all the stratified rocks of the district, and who accompanied the writer along the shore-line, regarded the rocks at Bighouse as a repetition of the beds exposed further to the east; even actually predicting to the writer the sequence before the rocks were reached. So perfect an identity at *two parts* of an ascending series is highly improbable.

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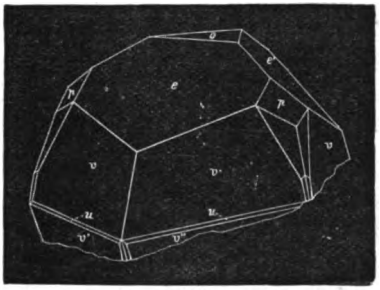
Only at two points in this extensive exposure did the writer observe minerals worthy of note.

The jointings in a freestone escarpment a short distance east of the Isauld Burn are lined with pseudomorphs of *limonite* after pyrite.

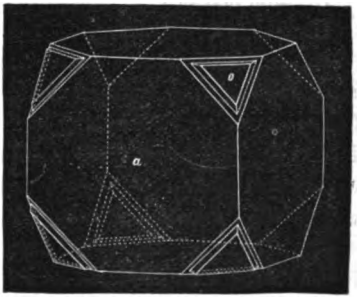
At Gie-uisg Geo, west of the Forss River there occur veins of calcite; these have a direction which bears directly on the veins of Hoy and the Stromness shore, and they may be a prolongation thereof.



The calcite of the veins is tinted brown from bitumen, and is confusedly crystalline. It carries the following minerals:—

Clear pellucid imbedded crystals of *calcite*, in the form drawn.

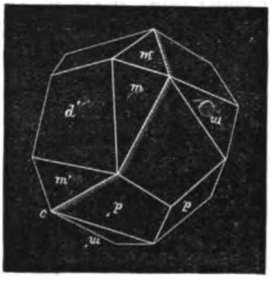
Bitumen in brilliantly black, hard, and brittle lumps.



Galena always in crystals of cubo-octahedron, as figured.

Pyrite in pale-coloured crystalline coatings, and on blende.

Brown *blende* in twins of *d m* arranged as a coating, and in linear aggregations of twin octohedra—the latter rare.



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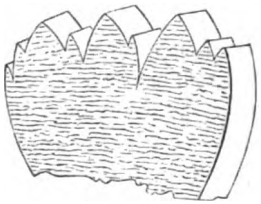
Marcasite, very rarely, as in figure.



All these are imbedded in calcite, there are no cavities. The lead is not in sufficient quantity to pay.

The following partial analyses of the flagstones from Castle Hill quarry have been published by Dr. Hoffmann:—

	Bottom Flag.	Middle Flag.	Top Flag.
Silica and Silicates insol. in HCl ...	61.39	69·45	68·40
Alumina and Ferric Oxide ...	4·87	11·50	10·21
Carbonate of Lime	21·91	10·66	10·93
Salts of Magnesia, the Alkalies, &c.	8·23	2·20	6·16
Organic matter	3·40	5.79	3·88
Loss at 100°	·20	·40	·42

But little information can be derived from the above; it can hardly be admitted that they "confirm the view that the great tenacity of these flags is in all probability due to the fine admixture of silica and alumina." It may be said to be well for the rocks, as also well for those who utilise rocks, that their components are united by a force of somewhat greater energy than mere *fine admixture*.

On account of the much larger proportion of carbonate of lime in the bottom flags, these should be set apart for special uses. The calcareous beds of this formation are low down in the series, and we have the same thing in these flag quarries also.

Associated with these flagstones and in many other parts of Caithness there are dark bituminoid flags very similar to those already described as found in Walls or Orkney.

Dr. Hofmann has given the following analysis of one such:—

Silica and insoluble Silicates	69·96
Alumina and Ferric Oxide	8·15
Carbonate of Lime	7·72
Salts of Magnesia, the Alkalies, &c. ...	2·91
Organic matter	10·78
Loss at 200°	·58
	100·00

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A much more highly bituminoid shale from near Barrogill Castle was also analysed by Dr. Hofmann. This yielded :—

Fixed matter, consisting of silicate of alumina, ferric-oxide, and sulphate of lime, with some phosphoric acid ...	69·79
Organic matter	30·21
	100·00

One ton of the material furnishes 2690 cubic feet of a highly luminous gas nearly entirely free from sulphur. The residue in the retort contained 8·5 p.c. of carbon.

Trias, Lias, and Oolite.

The narrow belts of these rocks lie in the east of the country. But few minerals are to be looked for in such recent strata. Dr. Joass has them under his immediate eye, and Professor Judd took them into his immediate keeping.*

Dr. Joass sent me cherty nodules from the trassic strip which occurs at the mouth of Dunrobin Burn; he desired an opinion as to their being correlated with the so-called cherty rock of Stotfield on the opposite coast. I could not do more than recognise a general similitude. The Dunrobin specimens are true cherty, coagulated, *colloidal* silica; the Stotfield is, for the most part, *crystalloidal*, sheathing smaller quantities of the *colloidal*.

Doubtless there are many analyses of the Brora Coal. I give the following :—

Its colour was black, lustrous and brittle like "cherry." Specific gravity 1·878.

It yielded :—

Water	11·494
Gas	85·077
Carbon	45·183
Ash	8·246
	100 (H.)

A fissile shale which forms a band about one a and half inches in thickness in the middle of the coal, and which had a brown colour and a specific gravity of 1.825, yielded :—

* I have qualitatively and to a certain extent quantitatively, examined specimens from each of the above rocks with a view of seeing if they can by analysis be distinguished from the dolomites of the west. I found them to be all more or less dolomitic, and they can be readily distinguished by the presence of alumina and of phosphates. Taken as a whole they are not nearly so pure as is the rock at Assynt.

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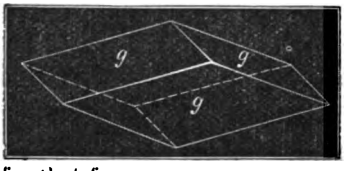
Water	6·247
Gas	20·338
Carbon	19·72
Ash	53·895
	100

(H.)

From boulders of the upper oolite lying near Culgower, Dr. Joass sent me septarian veins which carried *calcite* in three forms. The ordinary "nail head" (*g*) as figured, *c g*, and the "dog-tooth," which latter invariably lay upon their sides. This is an unusual position for that form.



Dr. Gunn here found, in similar but more siliceous specimens, round drops or globules of *asphalt* imbedded in thin veins of calcite: these drops were jet black, rich brown in thin splinters, perfectly spherical, and of high lustre. *Galena* is associated with the mineral. Unfortunately there was not a sufficiency of the asphalt for analysis, but I found it to be perfectly soluble in benzole, and to burn, when heated, with a brilliant smoky flame.

No radiating structure could be seen in the globules when broken, but a concentric one was sometimes visible; and the round drops sometimes had a perfectly spherical central hollow, with a brilliantly lustrous inner surface. Fractured chips with sharp angles also lay among brecciated portions of the calcite. The latter when dissolved in acid leave a thin film of volatile oil. Doubtless this asphalt is of fissile origin, and the mode or method of segregation of these spheres is very difficult of explanation. Can it have been that it was soluble in or combined with the calcite up to the time of the latter crystallising? Tarry masses of it occur in micaceous rock in Fife, and in dolerite in Skye, in similar association, and at these places the calcite also contains it in considerable amount; indeed calcite contains it sometimes as a colouring matter when no separate bitumen is visible, as at Kinghorn in Fife.

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On the Crystalline Form of Meneghinite.

By H. A. Miers, B.A., Assistant in the Mineral Department, British Museum.

Read before the Crystallological Society, July 3rd, 1883.

A complete description of this mineral was given in Poggendorf's *Annalen*, vol. 132 (1867), p. 372, by Prof. vom Rath, who ascribed it to the oblique system with the elements, $a : b : c = \cdot 361639 : 1 : \cdot 116825$; $\beta = 87°40'18''$.

This paper gives a full account of the appearance and properties of the Meneghinite from Serravezza, and of its association with Quartz, Galena, Blende, Chalybite, Copper Pyrites, Iron Pyrites, Calcite, and Albite; the results of the analysis also accord fairly with the previous determinations of Bechi and Hofmann, which give for the formula $Pb_4\ Sb_2\ S_7$ or $4Pb\ S + Sb_2\ S_3$.

The determination of the crystallographic elements is attended with some difficulty in consequence of the minute size of the end faces which are seldom found; in fact the values given by Prof. vom Rath appear to be mainly derived from a single crystal (fig. 2. *loc. cit.*), the measurement of which was repeated by Hessenberg. The original observations of Sella (*Gazz. Uffic. d. R. d' Italia*, 1862) as quoted by vom Rath, placed the mineral in the Rhombic system; but the only two measurements which his crystals yielded were the prism angle of 46°33′ ($=b\ T$) and the angle from the basal plane on to a dome 18°59′ ($=cd$). The apparently Rhombic symmetry of the crystals was explained by vom Rath as a result of twinning on the face 100.

Three specimens in the British Museum afforded twelve small needles with terminal faces, from which were obtained the results given below; these results were confirmed, and two forms added, by two crystals from a specimen in the Ludlam collection which I was enabled to examine through the kindness of Mr. Rudler.

These specimens are all from the Bottino mine near Serravezza, in Tuscany, where Meneghinite occurs as striated needles and slender prisms of bright metallic lustre associated with the above-mentioned minerals, and also Jamesonite, Boulangerite, and Mispickel. (*Achiardi, Mineralogia della Toscana*, ii. 350.)

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The crystals generally betray a tendency to grouping in parallel aggregations, and to this is perhaps to be ascribed the deep channeling of the prisms, and the frequent unevenness and broken nature of the terminal faces. The following are the results of the measurements made with a Fuess goniometer :—

Rhombic. $a : b : c = 1{\cdot}89046 : 1 : {\cdot}68664$.

$100 : 110 = 62°7'21''$. $010 : 011 = 55°31'30''$. $001 : 101 = 19°57'32''$.

$a = 100$	$t = 212$	$e = 230$	$U = 410$	$x = 24, 18, 13$
$b = 010$	$u = 414$	$S = 430$	$h = 10, 1, 0$	$q = 24, 0, 11$
$c = 001$	$n = 101$	$l = 320$	$k = 12, 1, 0$	$\delta = 0, 6, 13$
$r = 111$	$m = 110$	$f = 530$	$\psi = 24, 12, 13$	$o = 023$
$v = 011$	$\mu = 814$	$T = 210$	$\pi = 24, 24, 13$	$y = 038$
$d = 012$	$\lambda = 24, 6, 13$	$g = 310$	$\rho = 24, 12, 11$	$\theta = 045$ (vom Rath)
$s = 434$	$\beta = 412$	$i = 720$	$\sigma = 24, 6, 11$	$w = 051$ (vom Rath).

	Calculated.	Observed.	No. of edges.		Calculated.	Observed.	No. of edges.		Calculated.	Observed.	No. of edges.
bv		55°31½′	18	*bU*	64°42¼′	64°35′	3	*dr*	22°38′	22°35′	2
bs		64°10¼′	10	*bh*	79°17¾′	79°4′	2	*ds*	19°40′	19°38′	2
br	57°9⅔′	57°8′	10	*bk*	81°2¾′	80°59′	3	*dt*	18°57½′	19°4′	7
bt	72°7′	72°4′	14	*bn*	90°0′	90°0′	8	*du*	21°40′		
bu	80°50′	80°50′	14	*aq*	51°36¼′	51°53′	1	*dn*	27°15′	27°9′	1
an	70°2½′	70°2′	2	*bμ*	82°5½′	82°14′	7	*dμ*	36°37′	36°38′	3
bd	71°8′	71°3½′	2	*aμ*	54°24′	54°30′	3	*dλ*	32°36¾′	32°37′	3
ar	73°20′	73°18′	2	*bλ*	75°15½′	75°9′	10	*dβ*	34°29½′	34°34′	1
as	72°6¼′	72°12′	1	*aλ*	57°25′	57°26′	2	*vr*	16°40′		
at	71°2⅔′	71°1′	3	*bσ*	73°38½′	73°46½′	2	*vs*	19°15½′		
au	70°17⅜′	70°18′	4	*aσ*	53°25½′	53°22′	1	*vt*	24°19½′		
bo	65°24½′	65°41′	2	*bψ*	62°14′	62°9′	3	*vu*	31°13⅜′	31°14′	1
by	75°33⅜′	75°43′	2	*bx*	51°42′	51°29′	1	*vn*	39°12½′		
bθ	61°15¼′			*bπ*	43°31¼′	43°22′	1	*vμ*	39°37′		
bδ	72°25′			*bρ*	59°35′	59°38½′	1	*vλ*	36°16½′		
bw	16°14⅓′			*aψ*	60°28⅜′	59°50′	1	*vβ*	37°25⅜′		
bm	27°52⅜′	27°19′	1	*aρ*	57°37′			*rβ*	22°36′	22°49′	1
be	19°25½′	19°34′	4	*Tρ*	42°31¼′	42°26′	1				
bS	35°11¾′	35°26′	9	*Tψ*	47°18′	47°9′	1				
bl	38°25¾′	38°0′	1	*Uλ*	53°26′	53°19′	1				
bf	41°24′	41°35′	1	*Uσ*	48°45¾′	48°46′	1				
bT	46°36¾′	46°35′	7	*Tt*	68°26⅜′	63°25′	1				
bg	57°47′	56°45′	3	*bβ*	74°28′	74°28½′	1				
bi	61°37½′	61°47′	3	*aβ*	55°30½′						

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Fig. I. gives a general view of the most important forms and their relative development; but the crystals are, as a rule, very unsymmetrical in appearance.

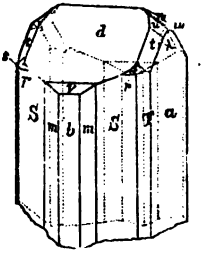

Fig. I.

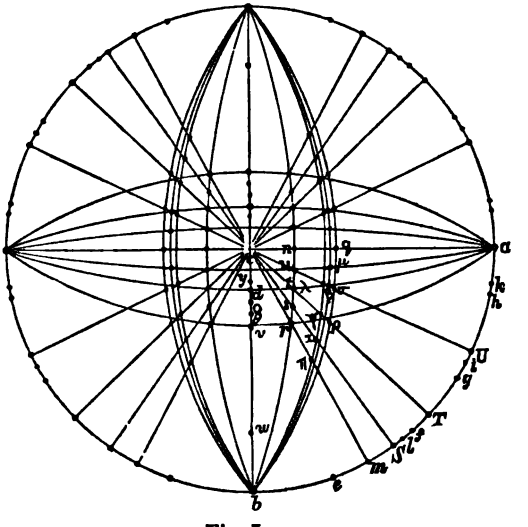

Fig. Ia.

The zone *b v d*, which contains the largest faces, was found on almost all the crystals, and was determined, wherever measurements on to the prism zone were possible, to be perpendicular to that zone. In the prism zone itself measurements were extremely difficult in consequence of the deep striations which generally give rise to a continuous series of banded images as the crystal is turned round; the angles given for this zone in the above table are therefore chosen only from faces which gave a single though in many cases a broad image. Of these, *b* is always smooth and bright; the faces *f T U K a S e* were also observed as broad bright planes giving good images in isolated cases, but *a* is rarely present. The end faces with the exception of *v* and *d*, though very bright, are almost always very minute, and are sometimes barely recognisable under the lens. Observations from them could be only in general made with the δ eyepiece of Fuess's goniometer.

It is fortunate therefore that the positions assigned to these faces were fully confirmed by a very well-developed crystal, represented in Fig. II., which is somewhat larger than the others, and on which even the smaller faces can be recognised without difficulty. The values of the angles *bv* and *bs*, used above as parametral angles, are identical with those derived from this crystal, on which scarcely a single

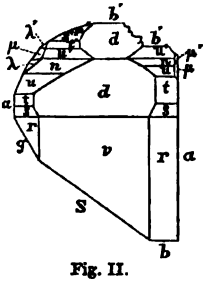

Fig. II.

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measurement differed as much as ten minutes from the calculated value; the majority not more than three or four minutes. (In comparison with this, the measurements upon the other crystals must be regarded as more doubtful.)

It may be mentioned, however, that the best value of *ab* is 89°36, while opposite faces of *a* and *b* are not strictly parallel.

The positions of the faces λ and μ were determined with considerable accuracy as follows:—

	Observed.	Calculated.
$b\mu = 010 : 8\bar{1}4$	=82°10′	
$b\mu = 0\bar{1}0 : 8\bar{1}4$	=82°0′	82°5½′
$b\mu = 0\bar{1}0 : 8\bar{1}4$	=82°8′	
$b\lambda = 010 : \bar{2}\bar{4},6,13$	=75°10′	
		75°15½′
$b\mu = 0\bar{1}0 : \bar{2}\bar{4},\bar{6},13$	=75°15′	
$d\mu = 012 : 8\bar{1}4$	=44°24′	
		44°30½′
$d\mu = 012 : \bar{8}\bar{1}4$	=44°25′	
$d\mu = 012 : 8\bar{1}4$	=36°42′	36°37′
$d\lambda = 012 : \bar{2}\bar{4},6,13$	=32°34′	32°36½′

In addition to its superiority in size and development, this crystal is distinguished from the others by the perfect symmetry of the plane *d*, both angles *bd* being 71°8½′.

In all other cases considerable variations were found in the angle *bd*, which extends from 69°30′ to 72°18′, having generally a value between 70°40′ and 70°50′, but rarely the same on both sides of *c*; *bv* also varies between 55°26′ and 55°36′; generally about 55°30.′

It is in consequence of the variations in this zone that Prof. vom Rath has ascribed the mineral to the oblique system, taking as parametral crystal that represented in fig. II. *loc. cit.*, in which on one side of *c* are two faces distant respectively 70°0′ and 71°47′ from the cleavage face; and on the other side one distant 70°1′ from the opposite cleavage face.

Of these angles 71°47′ I have not observed in any case; 70°5½′ was found upon one crystal; but *bd* seems to have generally a value about 70°40′, sometimes about 69°40′, and sometimes about 72°.

The angle *dd*′ (=012 : 0$\bar{1}$2) is given below for a number of cases in which the measurements can be relied upon to five or six minutes; with *bd*, *b*′*d*′, *bv*, *b*′*v*′.

	dd′	*bd*	*b*′*d*′	*bv*	*b*′*v*′	
1.	38°45′	70°15½′	70°59½′	55°31½′	55°34′.	
	or 38°19′	70°41½′	70°59½′			
2.	37°53′	71°3½′	71°3½′	55°31½′		(Fig. II.)
3.	38°11½′	69°30½′	72°18′		55°33′½.	
	or 40°47½′	69°30½′	69°42′			

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4.	36°55½′	71°2′	72°2½′	55°26′	55°29′.
5.	38°20′	70°32′	70°46′	55°32′	55°29′.
6.	38°17½′	70°49′	70°53½′	55°31½′	

Besides the above, the following very definite values were obtained for the angle between *b* and the largest and brightest of the faces in this zone:—65°40′; 69°41′; 70°5½′; 70°44′; 75°26′.

It seems probable, therefore, that the position of the face *d* is subject to very considerable and irregular variations; and in some cases it appears necessary to ascribe it to the forms (0,6,18,) or (038). The above table discloses no regularity in this variation, and suggests no further explanation of the crystal measured by Prof. vom Rath and Hessenberg, which gives such definite results, and yet differs widely from the crystal represented here in Fig. II.

The zone [*brstun*], faces of which were observed well-developed on eight crystals, offers a much greater constancy. In five crystals the angle between the zones [*br*] and [*bd*] was determined to be 19°58′; 20°0′; 19°57′; 20°0′; 19°59′; 20°34′; 19°2′; 19°44′; the first four of these being probably the best values; while *br*, *bs*, *bt*, *bu*, rarely differ more than 5 or 6 minutes from the calculated angles. Faces of the form μ were found on five, faces of λ on six crystals. The positions on Fig. IV. of π ρ σ and the angles Uλ, 1ψ, Tt, will be found in the first table given above. The other most important observations on this crystal are $b\psi$= 62°12′; $b\lambda$=75°14′.

The face β was observed on one crystal in conjunction with *bvdreμtu*, and was determined by the measurements.

	Observed.	Calculated.
$b\beta$	74°28′	74°28½′
$\bar{2}30 : 412 = e\beta$	86°19½′	86°19⅔′.
be	19°25½	19°25⅓′

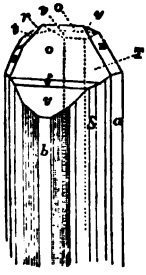

Fig. III.

It might appear from the stereographic projection that the zones [b x ψ λ] and [b ρ σ q] are merely distortions of the zone [b μ] to which they are inclined at angles of 2°9′ and 2°24′ respectively. But the faces ρ σ were found in conjunction with π ψ λ on a crystal from the Ludlam specimen (Fig. IV.), and q x ψ λ with μ and σ on a crystal from one of the British Museum specimens.

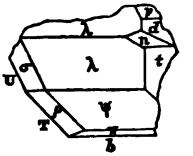

Fig. IV.

That neither λ nor σ are to be confused with (412), nor ψ nor ρ with (211), will be seen from the calculated angles:—

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100,412=55°30½′.	100,211=59°5½′.
010.412=74°28½′.	010,211=60°56½′.

The following table gives the greatest variations in the principal observed angles where fairly definite images were obtained:—

bv 55°22′ to 55°36′	*b*λ 75°0′ to 75°47′.
br 56°41′ „ 57°20′	*a*λ 57°21′ „ 57°31′.
bs 63°47′ „ 64°17′	*b*ψ 62°5′ „ 62°12′.
bt 74°4′4 „ 72°16′	*bn* 89°56′ „ 90°10′.
bu 80°44 „ 81°3′	*an* 70°2½′ „ 70°1½′.
ar 73°6′ „ 73°30′	
at 70°54′ „ 71°9′	
au 70°11′ „ 70°20′	
*b*μ 82°8′ „ 82°34′	
*a*μ 54°21′ „ 54°36′	

It may be mentioned that one crystal presented the appearance of Fig. III., in which $bv=55°84'$; $bo=65°41'$; $b\delta=72°18'$; $bv'=124°26'$; so that δo is a re-entrant angle. The faces *f* and *U* also occurred as large bright planes in two other cases, having a second individual upon them apparently in parallel position.

Any external appearance however of a twin structure is generally confined to the zone [*bvd*]; the faces *rstu* being constant in position and fairly symmetrical. The basal plane *c* has been observed as the only terminal face (somewhat dull) in at least one case.

As regards the physical characters of these specimens, there is a perfect but occasionally uneven cleavage parallel to *b*; also a smooth basal cleavage, which is not however always easy to obtain. On the Ludlam specimen the needles are mostly arranged in roughly parallel positions, frequently show a bright and perfect basal cleavage, and are partly covered with a thick black or deep brown incrustation.

Fracture conchoidal. Specific gravity of a bright crystallised mass weighing ·9188 of a gramme, and apparently consisting of pure Meneghinite 6·899. From this mass was taken the crystal mentioned above as exhibiting the form β.*

The formula given for Meneghinite corresponds to that of Jordanite $4PbS + As_2S_3$, and Prof. Groth has in consequence (*Tabellarische Uebersicht*, 1882, p. 29) endeavoured to explain the measurements of vom Rath as leading to the Rhombic system, and to the parameters of Jordanite. But it may be observed that (using vom Rath's notation) this makes the small bright face 2*x*, and the cleavage face a pair of prism-planes, while the new plane of symmetry *t* (302) was only once observed

* Two subsequent analyses of this specimen showed that it was far from homogeneous, the analyses differing widely.

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by vom Rath, and gave $at=61°55'$ instead of $62°45'$ as it should be on this assumption.

Using the axes and parameters here adopted, it is difficult to refer Jordanite to the same, while preserving the cleavage face as (010). The nearest comparisons that can be made between the two minerals are

Jordanite $c : b : \frac{2}{3} a = 2{\cdot}0308 : 1 : {\cdot}6719.$
Meneghinite $a : b : c = 1{\cdot}8904 : 1 : {\cdot}6866.$
or Jordanite $\frac{7}{3} a : b : \frac{1}{3} c = 1{\cdot}8812 : 1 : {\cdot}6769.$

In the first case Jordanite $010,011 = 26°13'$. $010, 450 = 56°6\frac{1}{2}'$.
Meneghinite $010,110 = 27°{\cdot}52\frac{2}{3}'$. $010,011 = 55°{\cdot}31\frac{1}{2}'$.
In the second case Jordanite $010,110 = 61°{\cdot}44\frac{1}{2}'$. $010,013 = 55°{\cdot}54\frac{1}{2}'$.
Meneghinite $010,720 = 61°{\cdot}37\frac{1}{2}'$. $010,011 = 55°{\cdot}31\frac{1}{2}'$.

It will be observed that two of the axes to which Meneghinite is here referred are equal to two of those of Stephanite, while the third is three times as great.

Stephanite $3b : a : c = 1{\cdot}8873 : 1 : {\cdot}6853.$
Meneghinite $a : b : c = 1{\cdot}8904 : 1 : {\cdot}6866.$

Note.—Immediately before the publication of the above, a paper on the same subject by Prof. Krenner has reached me. (*Zeitschrift der Ungarischen Geologischen Gesellschaft*, 1883.)

Prof. Krenner has come to the same conclusions respecting the system and parameters of the mineral, but has not observed the curious group of faces λ, ψ, π, ρ, σ.

The following is an identification of the forms observed by Profs. vom Rath and Krenner with those mentioned above :—

Von Rath.	Krenner.		Vom Rath.	Krenner.	
b	a	$a.$	m	n	$e.$
a	b	$b.$	$\frac{1}{3}m$	g	$S.$
$2p$, $2x$	y	$v.$		k	$U.$
p, x	x	$d.$		u	
n, o	o	$i.$		w	
s	s	$\beta.$		v	$n.$
e	e	$u.$		p	
d	d	$s.$		z	$\mu.$
$\frac{1}{3}m$	m	$T.$		q	$r.$
$\frac{2}{3}m$	l	$m.$			

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Note on Crystals of Calamine from Wanlockhead, Dumfries-shire.

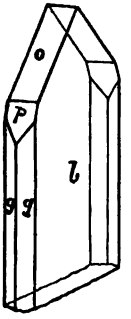
By J. Stuart Thomson.

[Read October 23rd, 1883.]

HYDRATED Silicate of Zinc or Calamine is known to occur in a crystalline form at Leadhills, Lanarkshire, but it does not appear to have been observed in this form, until recently, in the mines at the adjacent village of Wanlockhead; Greg and Lettsom only mentioning the stalactitic and botryoidal forms of this mineral as being found there. The specimens described in this note were given me by Dr. Wilson, who obtained them from the Bay Mine, Wanlockhead.

The crystals are small and cannot compare with those from some of the continental localities, the largest crystals which came under my notice being not more than from $\frac{1}{10}$th to $\frac{1}{8}$th of an inch in length; the form is, however, quite distinct, and the crystals are disposed in characteristic radial groupings. The colour varies from pale yellow to brown. When submitted to chemical tests, the crystals gave the usual reactions for a Silicate of Zinc, viz. they were decomposed by acids with separation of gelatinous Silica, which dissolved in a strong solution of Caustic Potash; the filtrate from the separated Silica gave a white precipitate with Ammonia, which was soluble in an excess of the reagent. When heated in a closed tube, the crystals decrepitated, gave off water and became white.

Dr. Trechmann has kindly furnished the following observations on the crystals:—



"Only the upper or analogous pole is developed, and the crystals are attached to the matrix by the lower and to one another by the *b* planes, thus forming small fanlike groups.

The observed forms are:—

(*Brooke and Miller.*)

b	=	*a*	=	$\infty P \breve{\infty}$	=	(010)
g	=	*m*	=	∞P	=	(110)
o	=	*e*	=	$P \bar{\infty}$	=	(101)
p	=	*w*	=	$3P \bar{\infty}$	=	(301)

A combination of the first three forms was formerly found at Leadhills in small acicular crystals."*

"The following angles were measured:—

			C.O.T. measured.	*Schrauf.*†	*Brooke and Miller.*
g : *b*	=		52° 0′	51° 55′	51° 57′
o : *o*	=		62° 39′	62° 46′	63° 20′
p : *p*	=		123° 0′	122° 40′	123° 14′

* Greg and Lettsom. Manual of the Mineralogy of Great Britain and Ireland 1858.
† Schrauf, Sitzungsberichte der Wiener Akademie. Bd. 38, 1859.

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Note on the Occurrence of Evansite in East Cheshire.

By Arthur Smith Woodward.
Communicated by T. Davies, F.G.S.

[Read October 23rd, 1883.]

In the volume of the "Philosophical Magazine" for July—December, 1864, the late Mr. David Forbes announced the discovery of a new mineral-phosphate from Zsetcznik, Gömör Comität, in Hungary, and published a detailed account of its physical properties and chemical composition. He proved it to be a highly hydrated phosphate of alumina, with a very small amount of silicate, having the probable formula, $8\ Al_2O_3, PO_5 + 18\ H_2O$, and proposed to designate it by the name of *Evansite*, after Mr. Brooke Evans, of Birmingham, who first brought the mineral under his notice, and who, until then, had imagined it to be a peculiar variety of Allophane.

Up to the present time, this comparatively new species does not appear to have been recorded as occurring in the British Isles, and the specimens exhibited are, perhaps, of unusual interest on that account. They are from a small fissure in the Yoredale Rocks, at Ratcliffe Wood, near Macclesfield, and though no very fine examples have yet been secured, a study of the present ones, together with other carefully collected fragments, is quite sufficient to leave no doubt as to the correctness of the identification here made. Dr. Burghardt, of the Victoria University, and Mr. Thomas Davies, of the British Museum, have both examined the specimens, and it is chiefly due to their kind suggestions and assistance that it is now possible to add the name of this interesting mineral to the British lists.

I first found the Evansite, at the locality named, on March 25th, 1882, and have, so far, only seen it in one small section. The proprietor of the quarries, however, states that he has several times observed similar incrustations in the cracks by which the rock is everywhere traversed, but, not knowing the nature of the glassy mineral, has not preserved any specimens: during the last twelve months none of the phosphate has been met with, but this fact is scarcely any guarantee of its extreme rarity, for it seems to occur only in the commercially-unprofitable shaly beds, and whenever possible these are avoided in the quarrying operations.

Owing partly to scarcity of material, and partly to unfortunate circumstances shortly after the time of discovery, I have not been able to complete a quantitative analysis, but qualitative results agree very well with those of Forbes in his original investigations. Further, on pulver-

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ising some of the British mineral, and igniting a portion in a crucible, the loss was slightly less than 40 per cent., equal to the amount of loss observed by Forbes when the Hungarian mineral was treated in the same manner. Carbonates being absent, the loss on ignition denotes the percentage of water.

With regard to physical properties, it may be remarked that the specimens exhibited are closely similar in general appearance to some of the examples of Hungarian Evansite in the Forbes Collection, preserved in the Museum of the Owens College, Manchester. The hardness is likewise the same,—*i.e.*, between 3 and 4.

As already stated, the fissure containing the Evansite, at Ratcliffe Wood, traverses, at the particular spot referred to, a layer of hard and soft shales; these are about four or five feet thick, and it is a noticeable fact that, although numerous fossil shells—chiefly Goniatites—are to be obtained from them, almost all of these occur merely as most indefinite traces, the original materials having been completely removed and not replaced. *Possibly* the phosphoric acid of the mineral alluded to in this note may have been derived from the organic remains, but it is somewhat difficult to understand how the decomposition of the molluscs alone would furnish a sufficient supply. No fish remains have been detected in the locality.

Intimately associated with the mineral, are brown iron ore, oxide of manganese, and calcite, the latter in places occurring in very minute crystals, sometimes with an amethystine tinge. A few yards distant, there have also been found minute, but beautifully perfect, crystals of iron pyrites, abundance of pearl-spar, and a few scattered crystalline grains of zinc-blende. For detailed particulars, however, reference may be made to a paper by myself, read before the Manchester Literary and Philosophical Society in April 1882, and subsequently printed in the Proceedings,* where the Evansite was incidentally mentioned, but not by name.

* "Proc. Manch. Lit. and Phil. Soc.," Vol. XXI. pp. 115 124; reprinted in the "Chemical News," June 2nd, 1882. A mistake occurs in this paper that it may be well to correct here. It is stated that the Evansite is sometimes pseudomorphic after organic matter, like the wad there referred to, but such is certainly not the case. —A. S. W.

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Reviews and Notices.

On the Probable Occurrence of Herderite in Maine.

By Wm. Earl Hidden.

(Communicated in a letter dated Newark, New Jersey, December 11th, 1883.)

TO Mr. Nathan H. Perry, of South Paris, Maine, an earnest and successful collector of Maine minerals, and the discoverer of many new mineral localities in his State, I am indebted for a few specimens of a dark oil-green mica, having implanted on it clear crystals of a mineral resembling some varieties of apatite. The preliminary examination which I have made makes it probable that the mineral is the rare species *Herderite*.* The crystals are short, terminated prisms, of from 1^{mm} to 1^{cm} in length and diameter, transparent to translucent. Surfaces smooth and not highly polished, but bright. Lustre greasy-vitreous. Streak white. Colourless to faintly yellowish. Hardness 5. Sp. Grav. 3. Crystals orthorhombic, with $I \wedge I = 116°$ (hand goniometer). Among the planes already observed are I, $i\text{-}\bar{\imath}$, O, three macrodomes, one brachydome and three octahedral pyramids. A partial qualitative examination has shown the presence of phosphorus in large quantities. A careful analysis is now under-way by Mr. J. B. Mackintosh, E.M., of the School of Mines, New York City, and will shortly be published, with a full account of the method of occurrence and the general physical characters of the mineral.

This mineral had been previously called topaz, from its resemblance to that species in form and colour, and also from the fact of its being found at Stoneham, Maine, near the pockets that yielded the fine crystals of topaz noticed in this Journal by G. F. Kunz (III. xxv. p. 161), but the absence of the characteristic basal cleavage and of the hardness of that mineral led me to make the observations whose results have been given.

[*Note.*—Since the above notice was received from Mr. Hidden, the writer has had placed in his hands, by Professor Brush, a few crystals of the supposed *Herderite* from Maine; these specimens were sent by Mr. Perry. A partial examination of these crystals shows that they approximate closely in form to that given for *Herderite*, so that there can be but little doubt of the correctness of Mr. Hidden's determination. The crystals are prismatically developed in the direction of the brachydiagonal axis (see fig. 454, p. 546, Dana's Syst. Min.). The planes observed are: O

* Probably, according to trials by Plattner and Turner, an anhydrous phosphate of *alumina* and lime with fluorine, orthorhombic with $I \wedge I = 115° 53'$, G.= 2·985. Haidinger, *Phil. Mag.* IV. i. 1828. J. D. Dana's System Min., p. 546.

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(001), i-$\bar{i}$ (010), I (110), $\frac{1}{2}$-$\bar{i}$ (302), 1-$\bar{i}$ (011), 3-$\bar{i}$ (031), 6-$\bar{i}$ (061), $\frac{1}{2}$ (322), 3 (311). Of these planes all occur on *Herderite* except $\frac{1}{2}$-$\bar{i}$, 3-$\bar{i}$, $\frac{1}{2}$. The angles thus far obtained are only approximations, but they serve to show a close correspondence between the Main phosphate and *Herderite*, for example:—$I \wedge I = 116\frac{1}{2}°$, for *Herderite*=115° 53′; $O \wedge 1$-$\bar{i}$=156° 40′ for *Herderite*=156° 59′; $O \wedge 3$=112° 40′ for *Herderite*=112° 35′.—E. S. Dana.]—*American Journal of Science, Jan.* 1884.

On Native Lead from Maulmain, and Chromite from the Andaman Islands.

By F. R. Mallet, *Deputy Superintendent, Geological Survey of India.*

Native Lead.—Amongst a number of ores from the neighbourhood of Maulmain, in Burma, lately sent to the Geological Survey Office by Mr. G. H. Law, is one of a somewhat unusual character. It is a carbonate of lead, breaking with a rather largely facetted crystalline fracture, and having a bright red colour due, apparently, to an intimate admixture of minium. The mineral contains small cavities lined by minute white crystals of ordinary cerussite, and some of the cavities are partly filled with metallic lead. The above-mentioned substance has the appearance of a natural product, but the precaution was taken of writing to Mr. Law on this point, and in reply he states that it is "natural and not artificial." As native lead is a mineral of rare occurrence, its discovery in a new locality is worth putting on record.

Red carbonate of lead similar to the above, except that the native metal has not been observed in association with it, has been found also in the Hazáribágh district of Chutia Nágpur.*

Chromite.—During the present month a block of ore was to be sent to the Geological Survey Office, for examination, from the Officiating Chief Commissioner of the Andaman and Nicobar Islands. Mr. M. V. Portman, Extra Assistant Superintendent, who visited the place where it was found, writes: "About 100 yards south of the village of Chuckergaon, on the bank of a small stream, was a mass of ore about 9 ins. thick and 4 ft. long. It was lying on the surface of the ground. On removing it, and digging round and underneath it, the rock appeared to be a coarse sandstone strongly impregnated with iron. No more ore was found on this spot, though it again appears in two places further down the valley in some considerable quantity, several hundredweight having been brought in. On examination of the rocks within a radius of 300 yards, I found granular and highly crystalline limestone, intersected by views of calcspar

* Records, G. S. I. Vol. VII. p. 35.

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in some instances 4 ins. thick, diorite, porphyritic trap, and coarse ferruginous sandstone." Chuckergaon, the village mentioned, appears to be close to Port Blair.

The ore proved on examination to be chromite. As this mineral is usually found in serpentine, and serpentine is known to occur in the neighourhood of Port Blair, there is a strong probability that the Andamanese chromite is no exception to the general rule. "Serpentine and gabbro are found largely developed south of Port Blair and on Rutland Island, and are doubtless intrusive." A "micro-crystalline syenite" was noticed in one locality by Mr. Kurz; it is doubtless a form of the dioritic rock found locally associated with the serpentine in Pegu."* It will have been remarked that Mr. Portman observed diorite, &c., close to the place where the chromite was found.

As chrome iron ore (chromite), of average quality, is worth about £10 a ton in England, the Port Blair mineral, if obtainable in considerable quantities, is well worth attention.

[From the *Records Geol. Survey of India*, Vol. XVI., 1883.]

Obituary.

Samuel Francis Bawden, whose untimely death is deplored by many friends, to whom his warm heart and generous disposition had endeared him, was born in London of Cornish parents in the year 1854. His family is well-known and much respected in the mining district of West Cornwall, where one or more members of it have been connected with mining for several generations. His grandfather was engaged as engineer in the construction of the West Cornwall Railway, one of the oldest railways in the United Kingdom; his father was for many years connected with the Carn Brea and other mines near Redruth; one of his uncles has been for a long time purser of West Basset Tin Mine, in his native parish of Illogan; and another, now retired from active life, was for many years manager of Messrs. Vivian's Nickel and Cobalt Works at Birmingham.

His relatives being thus engaged, it was natural to Mr. Bawden to turn his attention to metallurgical chemistry. While employed in various chemical works at St. Helen's, Glasgow, and Swansea among others, he embraced such opportunities as came within his reach to add theoretical knowledge to his practical acquaintance with Chemical, Mineralogical, and Metallurgical Science. At Swansea he was for some time a teacher of chemistry under

* W. T. Blanford, Manual of the Geology of India, part 2, p. 733.

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the Science and Art Department, and I have been assured that his teaching there was much appreciated for its clearness and definiteness by those who attended the classes.

In the year 1877 he entered the service of the Rio Tinto Company, as Chief Selector and Assayer at the mines. His diligence and general ability while engaged in this important work led to his promotion as chief of the Cementation Department, on the resignation of Mr. Alex. Hill in 1880; and this latter appointment he held up to the time of his death, having secured in it the approval of his superiors, the personal regard and esteem of his colleagues, and the hearty respect of those who were engaged under him.

During his residence at the mines, and partly in conjunction with Mr. Osborne, then chief of the Mining Department and now sub-manager, he worked out several important improvements in the treatment of the ores and products—among which may be specially mentioned the washing of the copper precipitate with dilute acid to remove arsenic, the treatment of the richer ores by the dry way in blast furnaces, together with certain improvements in the calcination of the ores, washing certain classes of ore with ferric liquors, &c. &c. He also made some successful experiments on a kind of modified "Hollway Process," which have so far not been pursued to their legitimate conclusion.

A serious illness, the effect of the climate, from which he suffered for several months in the summer of 1879, seemed to have left him by the end of that year; and from this time up till the month of May 1883, his health continued good, but in that month his old enemy "calentura," a severe form of fever and ague, reappeared, and he was ordered home to recruit his health. Under the influence of the pure air of Cornwall he seemed in a few months to have much improved, and he proceeded to London with a view of returning almost immediately to his duties at the mines. A relapse, however, took place, at first slight, but which speedily became alarming, and on the 3rd November 1883, in spite of the skilful aid of his physician Dr. Thin, he died of exhaustion, regretted by all who knew him, at the early age of 29. He leaves a young wife and infant daughter to bewail his loss.

Mr. Bawden was elected a Member of the Mineralogical Society in 1879, but his busy life at Rio Tinto prevented him from contributing to the Society's Magazine or from attending any of the meetings of the Society.

Rio Tinto, *Feb.* 1884. J. H. Collins.

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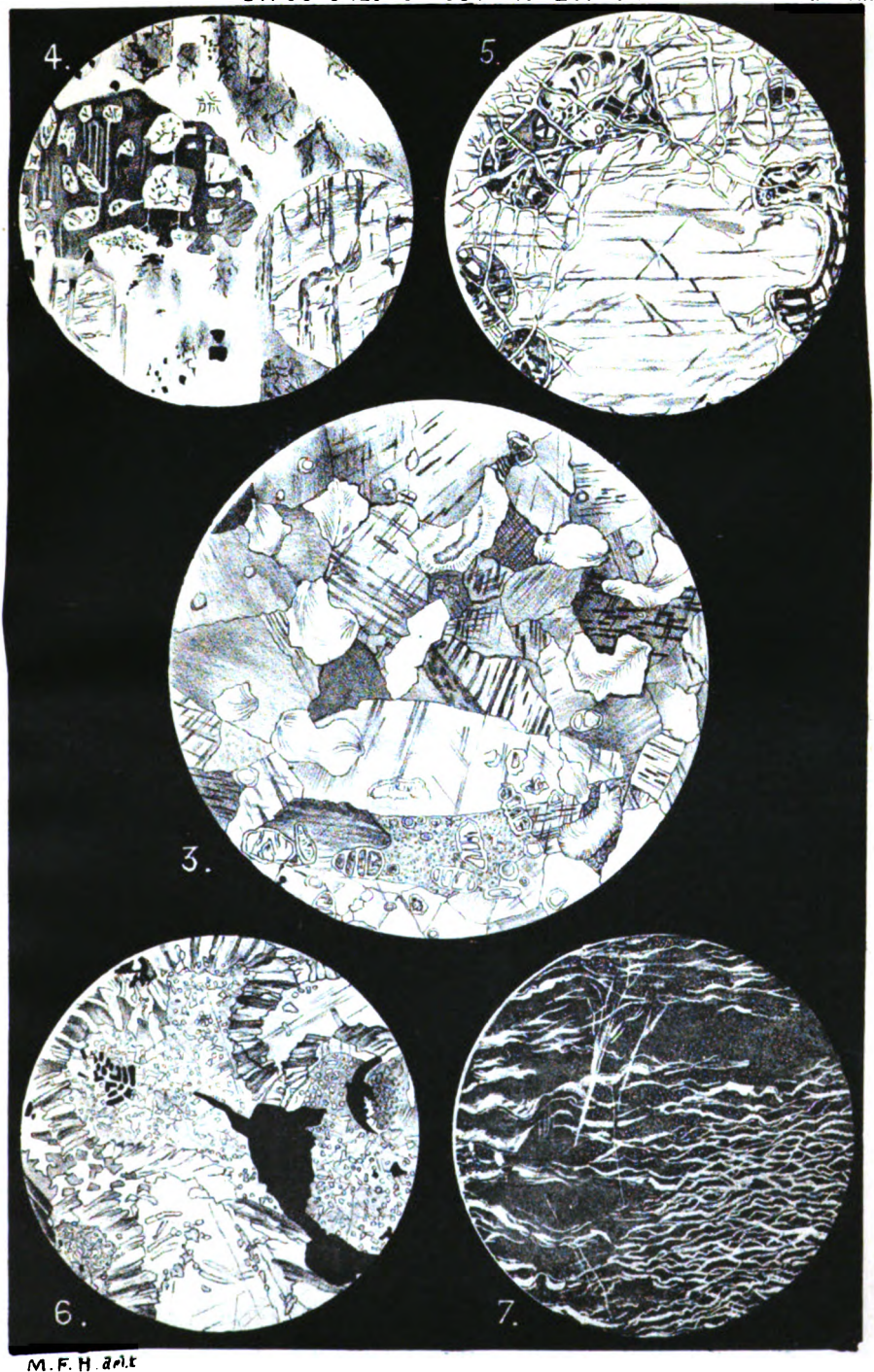

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